

Q
11
U563
CRLSSI

UNITED STATES NATIONAL MUSEUM

BULLETIN 218



Papers 1 to 11

CONTRIBUTIONS
FROM THE
MUSEUM
OF HISTORY AND
TECHNOLOGY

SMITHSONIAN INSTITUTION

WASHINGTON, D. C.

1959

SMITHSONIAN
INSTITUTION NOV 16 1959

ISSUED NOV 16 1959

SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM

REMINGTON KELLOGG
DIRECTOR

FRANK A. TAYLOR, *Director*
Museum of History and Technology

ALBERT C. SMITH, *Director*
Museum of Natural History

Publications of the United States National Museum

The scientific publications of the United States National Museum include two series, *Proceedings of the United States National Museum* and *United States National Museum Bulletin*.

In these series are published original articles and monographs dealing with the collections and work of the Museum and setting forth newly acquired facts in the fields of Anthropology, Biology, Geology, History, and Technology. Copies of each publication are distributed to libraries and scientific organizations and to specialists and others interested in the different subjects.

The *Proceedings*, begun in 1878, are intended for the publication, in separate form, of shorter papers. These are gathered in volumes, octavo in size, with the publication date of each paper recorded in the table of contents of the volume.

In the *Bulletin* series, the first of which was issued in 1875, appear longer, separate publications consisting of monographs (occasionally in several parts) and volumes in which are collected works on related subjects. *Bulletins* are either octavo or quarto in size, depending on the needs of the presentation. Since 1902 papers relating to the botanical collections of the Museum have been published in the *Bulletin* series under the heading *Contributions from the United States National Herbarium*.

JOHN S. ALV

Director, U.S. National Museum

LEO E. BIRCHMUTH, *Secretary*

FRANK DOLLAS, *Art Librarian*

UNITED STATES GOVERNMENT PRINTING OFFICE: WASHINGTON, 1959

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. • Price \$2.50

Papers

	Page
1. The Scholfield wool-carding machines	1
GRACE L. ROGERS	
2. John Deere's steel plow	15
EDWARD C. KENDALL	
3. The beginnings of cheap steel	27
PHILIP W. BISHOP	
4. The Auburndale Watch Company	49
EDWIN A. BALLISON	
5. Development of the phonograph at Alexander Graham Bell's Volta Laboratory	69
LESLIE J. NEWYELL	
6. On the origin of clockwork, perpetual motion devices, and the compass	81
DEREK J. DE SOLLA PRIO	
7. Mine pumping in Agricola's time and later	113
ROBERT P. MULLHUMP	
8. The natural philosophy of William Gilbert and his predecessors	121
W. JAMES KING	
9. Conestoga wagons in Braddock's campaign, 1755	141
DONALD H. BERKEBILL	
10. Old English patent medicines in America	155
GEORGE B. GRIFENHAGEN and JAMES HARVEY YOUNG	
11. Why Bewick succeeded: A note on the history of wood engraving	185
JACOB KAMEN	

Introduction

THE STAFF OF THE MUSEUM OF HISTORY AND TECHNOLOGY, a young subdivision of the Smithsonian Institution's United States National Museum is pleased to present this its first collection of published papers. This volume of the *United States National Museum Bulletin* series marks another step in the century-long effort of dedicated Smithsonian curators to develop a complete national museum of the United States—a museum which through its scholarly research and publications, as well as through its collections and exhibits, will increase and diffuse knowledge of the cultural, scientific, and technological history of the Nation, including its heritage from older cultures and scholarship.

This volume was conceived by Robert P. Multhauf, head curator of the Museum's Department of Science and Technology, as a tribute to Mr. Greville Bathe for his fine contributions to the history of technology. It is equally a recognition of the inspiration which the work of Bathe and other historians of science and engineering has provided, during the past quarter-century, to museum curators collecting and interpreting the objects that record our history.

Greville Bathe's stout works on Oliver Evans and Jacob Perkins and his entertaining *Engineer's miscellany* comprise in themselves a complete justification for the study of the history of technology. In *Oliver Evans* the view of the exciting period spanning the transition from American colonies to United States is illuminated as it seldom is in political or narrative history. Insights into the problems of authoring and publishing, the efforts of the colonies to encourage and protect inventors, remonstrances against the threat of technological unemployment, the struggle with the wilderness and all obstacles to communications, the promotion of manufactories west of the Alleghenies, consultations between the country's leaders and the mechanics, are only a few of the dividends found in this day to day account of great inventor and a daring risk-taker. In *Jacob Perkins*, Bathe describes a surprising export of skill and scientific inquiry from the new world to the old.

One cannot read these works—or the papers presented here—without recognizing that technological progress is a mainstream of cultural development. It is equally evident that these studies provide background for viewing present day problems in true perspective and that the knowledge they impart helps us to cope more successfully with technology's smashing impact on our lives.

It is encouraging that the time was found by the authors of these papers to study and write while they were engaged in planning facilities and exhibits for the new Museum of History and Technology building now under construction. This promises a program that will accelerate when the building is opened.

The imaginative design of this volume of the Bulletin series is the work of the Editorial and Publications Division of the Smithsonian Institution, with the assistance and cooperation of the Government Printing Office.

FRANK A. FAYLE, *Director*
MUSEUM OF HISTORY AND TECHNOLOGY

July 22, 1959
Washington, D.C.

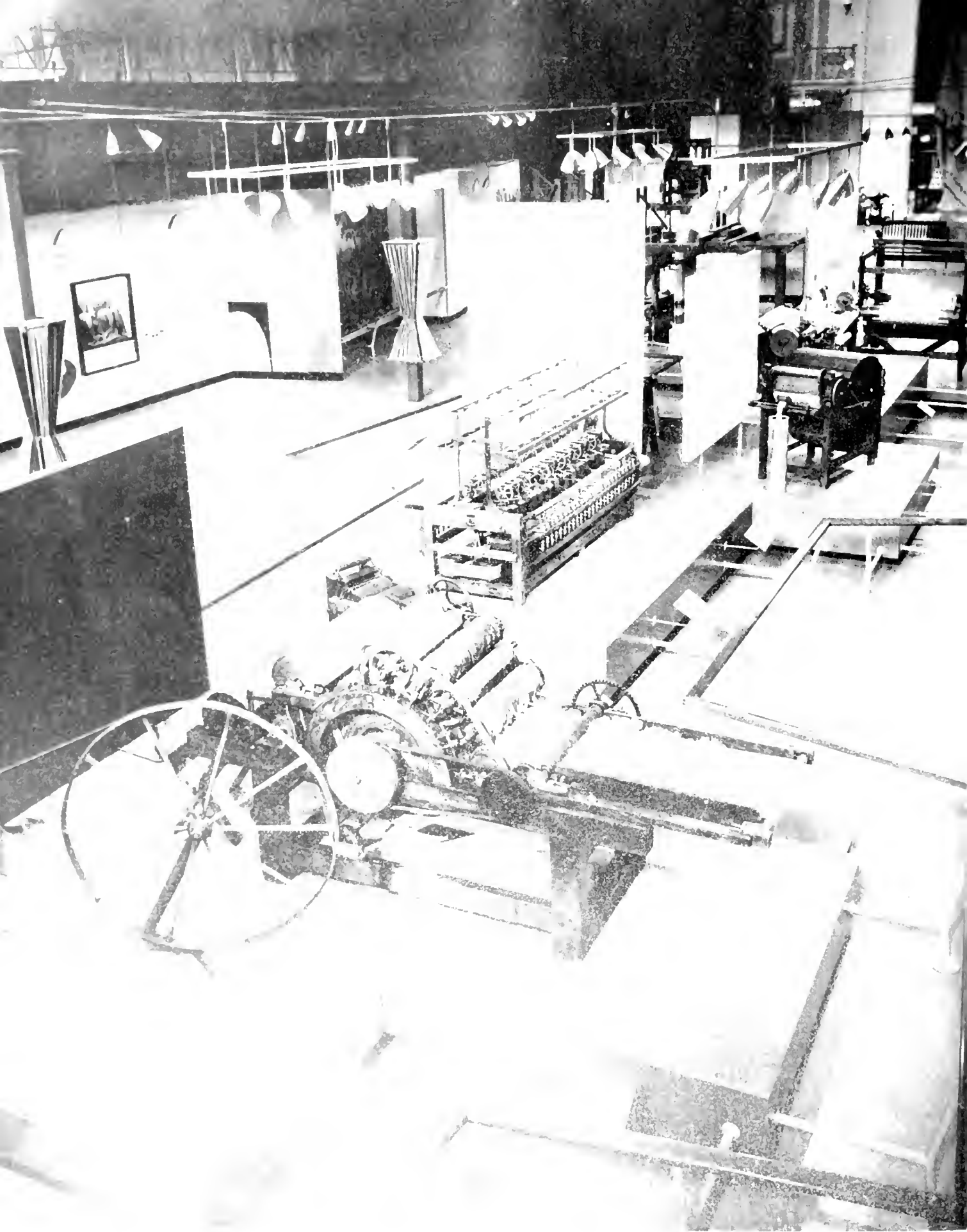
CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 1

THE SCHOLFIELD WOOL-CARDING MACHINES

Grace L. Rogers

PRIMITIVE CARDING	
THE FIRST MECHANICAL CARDS	
JOHN AND ARTHUR SCHOLFIELD	
THE NEWBURYPORT WOOLLEN MANUFACTORY	
THE SCHOLFIELD MACHINES	2



By Grace L. Rogers

THE SCHOLFIELD WOOL-CARDING MACHINES

First to appear among the inventions that sparked the industrial revolution in textile making was the flying shuttle, then various devices to spin thread and yarn, and lastly machines to card the raw fibers so they could be spun and woven. Carding is thus the important first step. For processing short-length wool fibers its mechanization proved most difficult to achieve.

To the United States in 1793 came John and Arthur Scholfield, bringing with them the knowledge of how to build a successful wool-carding machine. From this contribution to the technology of our then infant country developed another new industry.

THE AUTHOR: Grace L. Rogers is curator of textiles, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.

CARDING IS THE NECESSARY preliminary step by which individual short fibers of wool or cotton are separated and cleaned of foreign materials so they can be spun into yarn. The thoroughness of the carding determines the quality of the yarn, while the position in which the carded fibers are laid determines its type. The fibers are laid parallel in order to spin a smooth compact yarn, or they are crossed and intermingled to produce a soft bulky yarn.

Figure 1. AN ORIGINAL SCHOLFIELD WOOL-CARDING MACHINE, built by Arthur Scholfield or under his immediate direction between 1803 and 1814, as exhibited in the hall of textiles of the U. S. National Museum (cat. no. F11100). The exhibits in this hall are part of those being prepared for the enlarged hall of textiles in the new Museum of History and Technology now under construction. (Smithsonian photo 45306.)

Primitive Carding

The earliest method of carding wool was probably one in which, by use of the fingers alone, the tufts were pulled apart, the foreign particles loosened and extracted, and the fibers blended. Fuller's teasels (thistles with hooked points, *Dactylis glomerata*), now better known for raising the nap on woven woollens, were also used at a very early date for carding. The teasels were mounted on a pair of small rectangular frames with handles; and from this device developed the familiar small hand card (see fig. 2), measuring about 8 inches by 5 inches, in which card clothing (a wire tooth embedded in leather) was mounted on a board with the wire tooth bent and angled toward the handle. The wool was placed on one end and a second card was held against the wool and moved away from end to end. This action separated the fibers and laid them parallel to the direction of the film. As the fibers had been cleaned, the wool was



Figure 2. HAND CARDS "USED ON PLANTATION OF MARY C. PURVIS," NELSON COUNTY, VIRGINIA, during early 1800's and now in U. S. National Museum (*cat. no. 12818; Smithsonian photo 37258*).

Figure 3. THE FIRST MACHINE IN LEWIS PAUL'S BRITISH PATENT 636, ISSUED AUGUST 30, 1748. The treadle moved the card-covered board *B*1, in a horizontal direction as necessary to perform the carding operation. With the aid of the needstick the fibers were removed separately from each of the 16 cards *V*. The carded fibers were placed on a narrow cloth band, which unrolled from the small cylinder *G*, on the left, and was rolled up with the fibers on the cylinder *I*, at the right.

U.S. PATENT OFFICE
PAUL'S NEEDCARDER

SHEET 1
OF SHEETS

The Jaws & Policy that
serve about the Cylinder *G*



FIG 1st



eral times, the cards were turned so that the handles were together and once again they were pulled across each other. With the wire teeth now angled in the same direction, the action rolled the carded fibers into a sliver (a loose roll of untwisted fibers) that was the length of the hand card and about the diameter of the finger. This placed the wool fibers crosswise in relation to the length of the sliver, their best position for spinning.¹ Until the mid-18th century hand cards were the only type of implement available for carding.

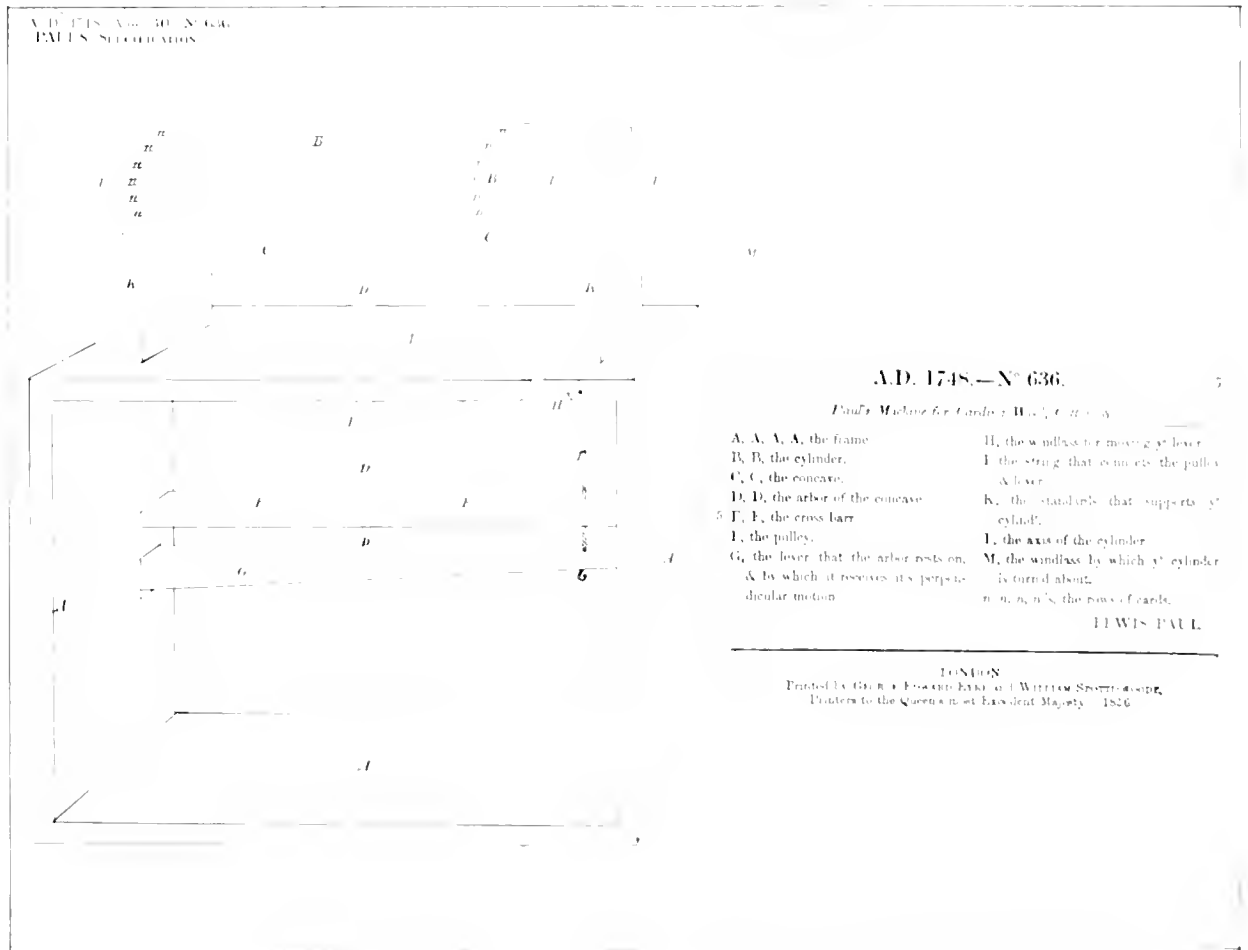
First Mechanical Cards

The earliest mechanical device for carding fibers

¹ The same type of hand cards were also used for cotton in Colonial America, but because the cotton fibers were not laid parallel in the sliver only coarse yarns could be spun. In ancient Peru the fibers for spinning fine cotton yarns were prepared with the fingers alone. In India the cotton fibers were combed with the fine-toothed jawbone of the boalee fish before the fibers were removed from the seed. (J. F. Watson, *The textile manufactures and the costumes of the people of India*, London, 1866, p. 64.)

was invented by Lewis Paul in England in 1738 but not patented until August 30, 1748. The patent described two machines. The first, and less important, machine consisted of 16 narrow cards mounted on a board; a single card held in the hand performed the actual carding operation (see fig. 3). The second machine utilized a horizontal cylinder covered with parallel rows of card clothing. Under the cylinder was a concave frame lined with similar card clothing. As the cylinder was turned, the cards on it worked against those on the concave frame, separating and straightening the fibers (see fig. 4). After the fibers were carded, the concave section was lowered and the fibers were stripped off by hand with a needle stick, an implement resembling a comb with very fine needlelike metal teeth. Though his machine was far from perfect, Lewis Paul had invented the carding

Figure 4.—THE PATENT DESCRIPTION OF PAUL'S SECOND MACHINE suggested that the fibers be carded by a cylinder action, but be removed in the same manner as directed in the first patent.



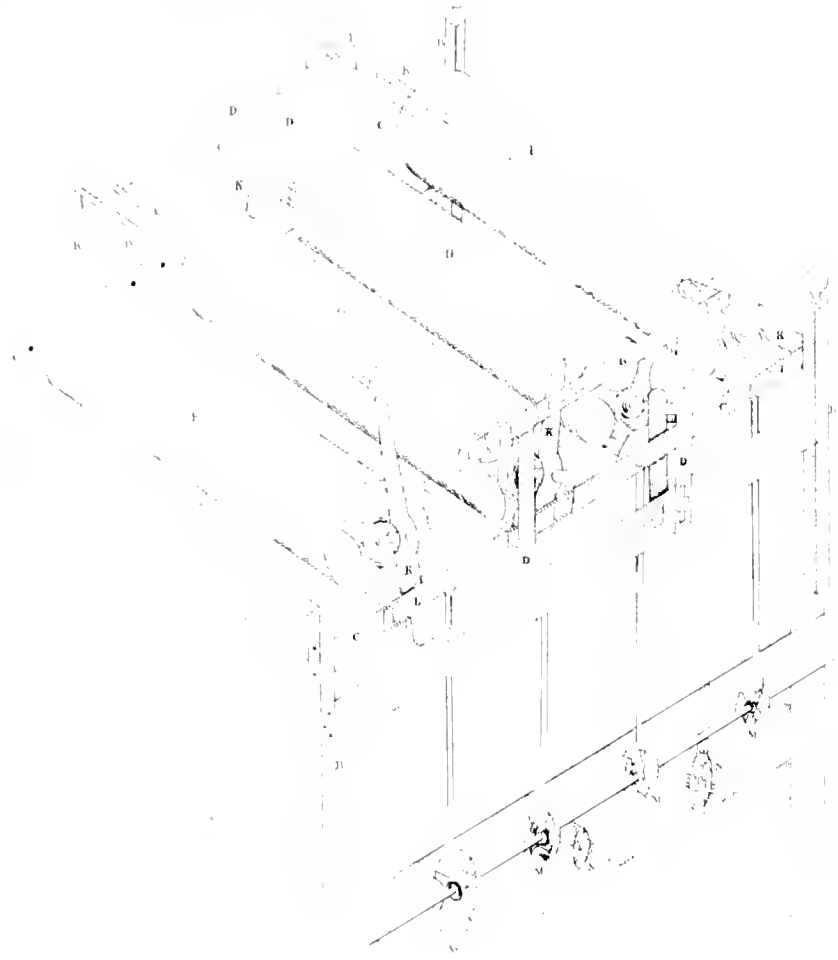
A.D. 1748.—N° 636.

Paul's Machine for Carding Wool, &c. &c.

- | | |
|---------------------------------------------------------------------------------------|------------------------------------------------------------------|
| A, A, A, the frame | H, the windlass for moving y ^e lever |
| B, B, the cylinder, | I, the string that connects the pulley & lever |
| C, C, the concave, | K, the stand or table that supports y ^e cylinder |
| D, D, the arbor of the concave | L, the axis of the cylinder |
| E, E, the cross bar | M, the windlass by which y ^e cylinder is turned about |
| F, the pulley, | n, n, n, the rows of cards |
| G, the lever that the arbor rests on, & by which it receives its perpendicular motion | |

LEWIS PAUL.

LONDON
Printed by GEORGE FORDON, Printer, in St. William Street, opposite
Printers to the Queen's most Excellent Majesty. 1748.



A Plan of the Machine for carding
by Daniel Bourn

The rollers are supported by a frame of wood, and are driven by a water wheel. The rollers are arranged in a row, and are of different diameters. The rollers are supported by a frame of wood, and are driven by a water wheel. The rollers are arranged in a row, and are of different diameters. The rollers are supported by a frame of wood, and are driven by a water wheel. The rollers are arranged in a row, and are of different diameters.

The rollers are supported by a frame of wood, and are driven by a water wheel. The rollers are arranged in a row, and are of different diameters. The rollers are supported by a frame of wood, and are driven by a water wheel. The rollers are arranged in a row, and are of different diameters.

- K The rollers are supported by a frame of wood.
- L The rollers are supported by a frame of wood.
- M The rollers are supported by a frame of wood.
- N The rollers are supported by a frame of wood.
- O The rollers are supported by a frame of wood.
- A B The rollers are supported by a frame of wood.

Daniel Bourn

Printed by J. G. & Co. at the Press of the Trustees of the British Museum, 1748.

FIG. 1. DRAWINGS FROM BRITISH PATENT 628, ISSUED JANUARY 20, 1748,
Daniel Bourn for a roller card machine.

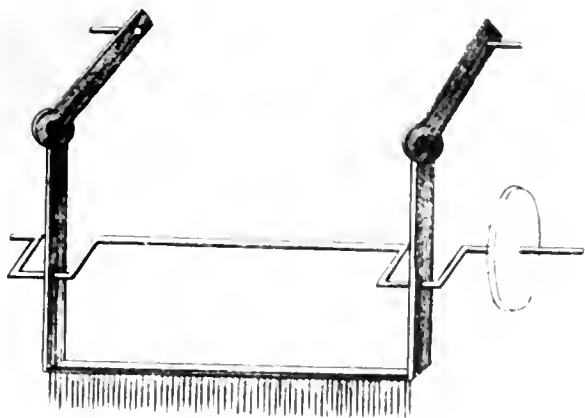


Figure 6. THE MOST IMPORTANT SINGLE FEATURE illustrated in Richard Arkwright's British patent 1111 of December 16, 1775, provided "a crank and a frame of iron with teeth" to remove the carded fibers from the cylinder.

cylinder working with stationary cards and the stripping comb.

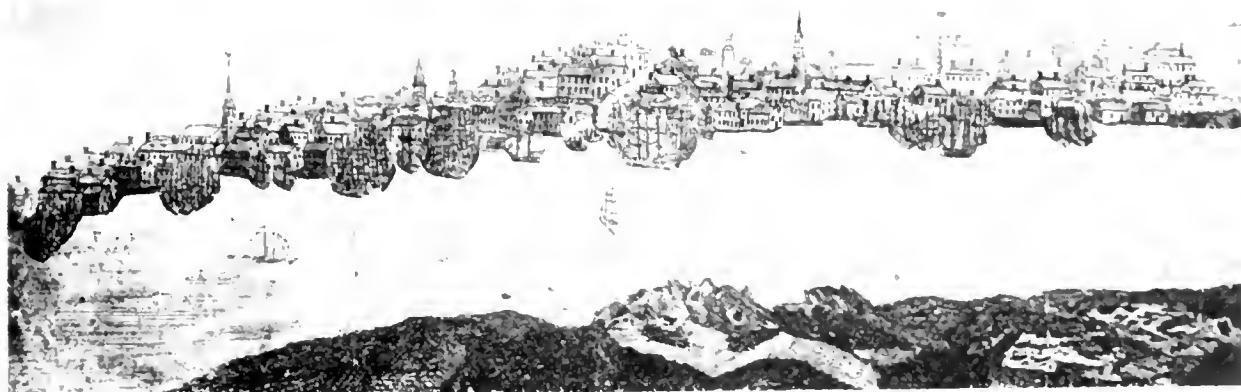
Another important British patent was granted in 1748 to Daniel Bourn, who invented a machine with four carding rollers set close together, the first of the roller-card type (see fig. 5). To produce a practical carding machine, however, several additional mechanical improvements were necessary. The first of these did not appear until more than two decades later, in 1772, when John Lees of Manchester is reported to have invented a machine featuring "a

perpetual revolving cloth, called a feeder, that led the fibers into the machine. Shortly afterward, the stripper rollers² and the doffer comb³ (a mechanical utilization of Paul's hand devices) were added. Both James Hargreaves and Richard Arkwright claimed to be the inventor of these improvements, but it was Arkwright who, in 1775, first patented these ideas. His comb and crank (see fig. 6) provided a mechanical means by which the carded fibers could be removed from the cylinder. With this, the cylinder card became a practical machine. Arkwright continued the modification of the doffing end by drawing the carded fibers through a funnel and then passing them through two rollers. This produced a continuous sliver, a narrow ribbon of fibers ready to be spun into yarn. However, it was soon realized that the bulk characteristic desired in woolen yarns (but not desired in the compact types such as worsted yarns or cotton yarns) required that the wool be carded in a machine that would help produce this.

² Edward Baines, *History of the Cotton Manufacture in Great Britain*, London, 1835, p. 176.

³ The wire points of the worker roller pick up the fibers from the faster moving main cylinder, carding the fibers on contact. A stripping action takes place when the wires of the worker roller meet the points of the stripper roller in a "point to back" action. This arrangement is used to remove the wool from the worker and put it back on the wire teeth of the main cylinder. Illustrated in W. Van Bergen and H. R. Mauerberger, *Wool: an wool hand book*, New York, 1948, p. 451.

⁴ The doffer comb, a serrated metal plate the length of the rollers, removes the carded fibers from the last roller or doffer.



NE PROSPECT OF THE TOWN OF NEWBURY PORT.

Figure 7. NEWBURYPORT, MASSACHUSETTS, IN 1709, AN ENGRAVING FROM JOHN J. CURRIER—*History of Newburyport, Massachusetts, 1704-1900*, vol. 2, Newburyport, 1906, 99.

In carding wool it was found more effective to omit the flat stationary cards and to use only rollers to work the fibers. The method of preparing the sliver also had to be changed. Since it was necessary to remove the wool fibers crosswise in the sliver, a fluted wooden cylinder called a roller-bowl was used in conjunction with an under board or shell. As a given section of the carded wool was fed between the fluted cylinder and the board, the action of the cylinder rolled the fibers into a sliver about the diameter of the finger and the length of the cylinder. Although these were only 24-inch lengths as compared to the continuous sliver produced by the Arkwright cotton-carding machine,⁵ wool could still be carded with much more speed and thoroughness than with the small hand cards. This then was the state of mechanical wool carding in England in the 1790's as two experienced wool manufacturers, John and Arthur Scholfield, planned their trip to America.

John and Arthur Scholfield

The Scholfields, however, were not to be the first to introduce mechanical wool carding into America. Several attempts had been made prior to their arrival. In East Hartford, Connecticut, "about 1770 Elisha Pitkin had built a mill on the east side of Main Street near the old meeting-house and Hockanum Bridge, which was run by water-power, supplied by damming the Hockanum River. Here, beside grinding grain and plaster, was set up the first wool-carding machine in the state, and, it is believed, in the country."⁶ Samuel Mayall in Boston, about 1788 or 1789, set up a carding machine operated by horse power. In 1791 he moved to Gray, Maine, where he operated a shop for wool carding and cloth dressing.⁷ Of the machines used at the Hartford Woolen Manufactory, organized in 1788, a viewer reported he saw "two carding-engines, working by water, of a very inferior construction." They were further described as having "two large center cylinders in each, with two doffers,

⁵ This was no great disadvantage at this time, as wool was still being spun on the spinning wheel. The mechanical spinning of woolen yarns was an obstinate problem that was not solved until 1815-1820. At then was necessary to piece these 24-inch slivers together before they could be spun until 1826, when a device for the doffing of carded wool in a continuous sliver was perfected by an American, John Goulding, and patented by him.

⁶ A. P. Pitkin, *The History of the State of America*, Hartford, 1887, p. 107.

⁷ From a letter written in 1785 to Mayall's son; A. H. Cole, *The History of the State of Maine*, vol. 1, Cambridge, 1926, p. 90.

and only two working cylinders, of the breadth of bare sixteen inches, said to be invented by some person there."⁸ But these were isolated examples; most of the woolen mills of this period were like the one built in 1792 by John Manning in Ipswich, Massachusetts, where all the work of carding, spinning, and weaving was still performed by hand.

The Scholfields' knowledge of mechanical wool-processing was to find a welcome reception in this young nation now struggling for economic independence. The exact reason for their decision to embark for America is unknown. However, it may well be that they, like Samuel Slater⁹ some three years earlier, had learned of the bounties being offered by several state legislatures for the successful introduction of new textile machines.

Both John and Arthur were experienced in the manufacture of woolens. They were the sons of a clothier (during the 18th century, a person who performed the several operations in finishing cloth) and had been apprenticed to the trade. Arthur was 36 and a bachelor; John, a little younger, was married and had six children. Arthur and John, with his family, sailed from Liverpool in March 1793 and arrived in Boston some two months later. Upon arrival, their immediate concern was to find a dwelling place for John's family. Finally they were accommodated by Jedediah Morse, well-known author of *Morse's geography and gazetteer*, in a lodging in Charlestown, near Bunker Hill. In less than a month John began to build a spinning jenny and a hand loom, and soon the Scholfields started to produce woolen cloth. The two brothers were joined in the venture by John Shaw, a spinner and weaver who had migrated from England with them. Morse, being much impressed with some of the broadcloth they produced, was especially interested to find that John and Arthur understood the actual construction of the textile machines. Morse immediately recommended the Scholfields to some wealthy persons of Newburyport (see fig. 7), who were interested in sponsoring a new textile mill.

⁸ From a report of the visit of Henry Wainey in 1794, cited by W. R. Bagnall, *The textile industries of the United States*, Cambridge, 1893, p. 107.

⁹ Slater introduced the Arkwright system of carding and spinning cotton into America in 1790. Bringing neither plans nor models with him from which to build the machines, he relied instead on his detailed knowledge of their construction. England prohibited the export of textile machines, models, and plans, and even attempted to prevent skilled artisans from leaving the country. George S. White, *Memoir of Samuel Slater*, Philadelphia, 1836, pp. 37 and 71.

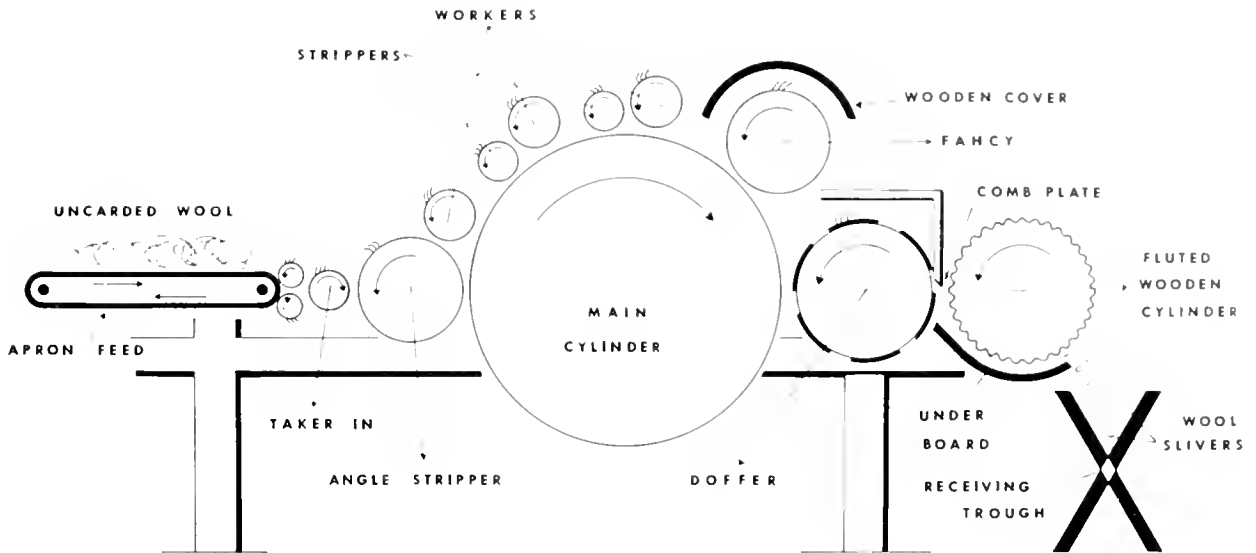


Figure 8. CROSS-SECTION OF A SCHOLFIELD WOOL-CARDING MACHINE. The wool was fed into the machine from a moving apron, locked in by a pair of rollers, and passed from the taker-in roller to the angle stripper. This latter roller transferred the wool on to the main cylinder and acted as a stripper for the first worker roller. After passing through two more workers and strippers, the wool was prepared for leaving the main cylinder by the fancy, a roller with longer wire teeth set to reach into the card clothing of the large cylinder. Then the doffer roller picked up the carded fibers from the main cylinder in 4-inch widths the length of the roller. These sections were freed by the comb plate, passed between the fluted wooden cylinder and an under board, where they were converted into slivers, and deposited into a small wooden trough.

The Newburyport Woolen Manufactory

A Newburyport philanthropist, Timothy Dexter, contributed the use of his stable. There, beginning in December 1793, the Scholfields built a 24-inch, single-cylinder, wool-carding machine. They completed it early in 1794, the first Scholfield wool-carding machine in America. The group was so impressed that they organized the Newburyport Woolen Manufactory. Arthur was hired as overseer of the carding and John as overseer of the weaving and also as company agent for the purchase of raw wool. A site was chosen on the Parker River in Byfield Parish, Newbury, where a building 100 feet long, about half as wide, and three stories high was constructed. To the new factory were moved the first carding machine, two double-carding machines, as well as spinning, weaving and fulling machines. The carding machines were built by Messrs. Standing, Armstrong, and Guppy, under the Scholfields' immediate direction. All the machinery with the exception of the looms was run by waterpower; the weaving was done

by hand. The enterprise was in full operation by 1795.

John and Arthur Scholfield (and John's 11-year-old son, James) worked at the Byfield factory for several years. During a wool-buying trip to Connecticut in 1798, John observed a valuable waterpower site at the mouth of the Oxoboxo River, in the town (i. e., township) of Montville, Connecticut. Here, the brothers decided, would be a good place to set up their own mill, and on April 19, 1799, they signed a 14-year lease for the water site, a dwelling house, a shop, and 17 acres of land. As soon as arrangements could be completed, Arthur, John, and the latter's family left for Montville.

The Scholfields quite probably did not take any of the textile machinery from the Byfield factory with them to Connecticut—first because the machines were built while the brothers were under hire and so were the property of the sponsors, and second because their knowledge of how to build the machines would have made it unnecessary to incur the inconvenience and

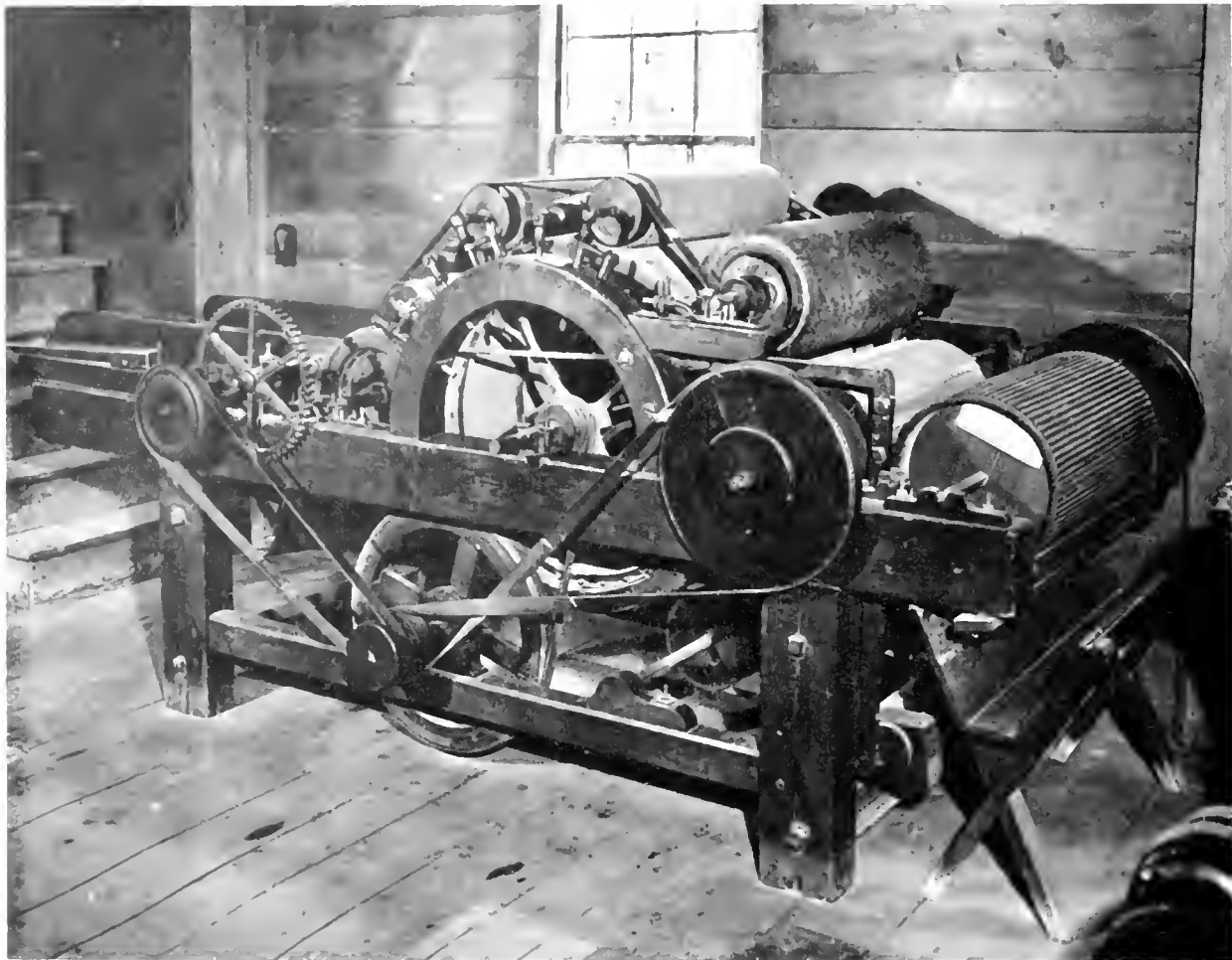


FIGURE 6. IN THE COLLECTION OF THE HENRY FORD MUSEUM, DEARBORN, MICHIGAN, IS THIS ORIGINAL SCHOLFIELD WOOL-CARDING MACHINE of the early 19th century. (Photo courtesy of the Henry Ford Museum.)

expense of transporting machines the hundred odd miles to Montville. However, John Scholfield's sons reported¹⁷ that they had taken a carding engine with them when they moved to Connecticut in 1799 and had later transferred it to a factory in Stonington. The sons claimed that the frame, cylinders, and legs of the machine were made of mahogany and that it had originally been imported from England. However, it would have been most uncommon for a textile machine, even an English one, to have been con-

structed of mahogany; and having built successful carding machines, the men at Byfield would have found it unnecessary to attempt the virtually impossible feat of importing an English one. If it ever existed and was taken to Connecticut, therefore, this machine was probably not a carding machine manufactured by the Scholfields. It is more probable that the first Scholfield carding machine remained in the Byfield mill as the property of the Newburyport Woolen Manufactory.

During the next half century, this mill was held by a number of individuals. William Bartlett and Moses Brown, two of the leading stockholders of the company, sold it in 1804 to John Lees, the English overseer who succeeded the Scholfields, and he continued to operate it for about 20 years. On August 24, 1824,

¹⁷ R. C. Scholfield, *History of the Manufacture of the Woolen Manufacture in Connecticut* (New Britain, 1882), pp. 17-18. The Scholfield family consisted of several sons still living in the 1880's, with the oldest son, John, being the only one; only James, and John's son, were still living in the Connecticut mill.

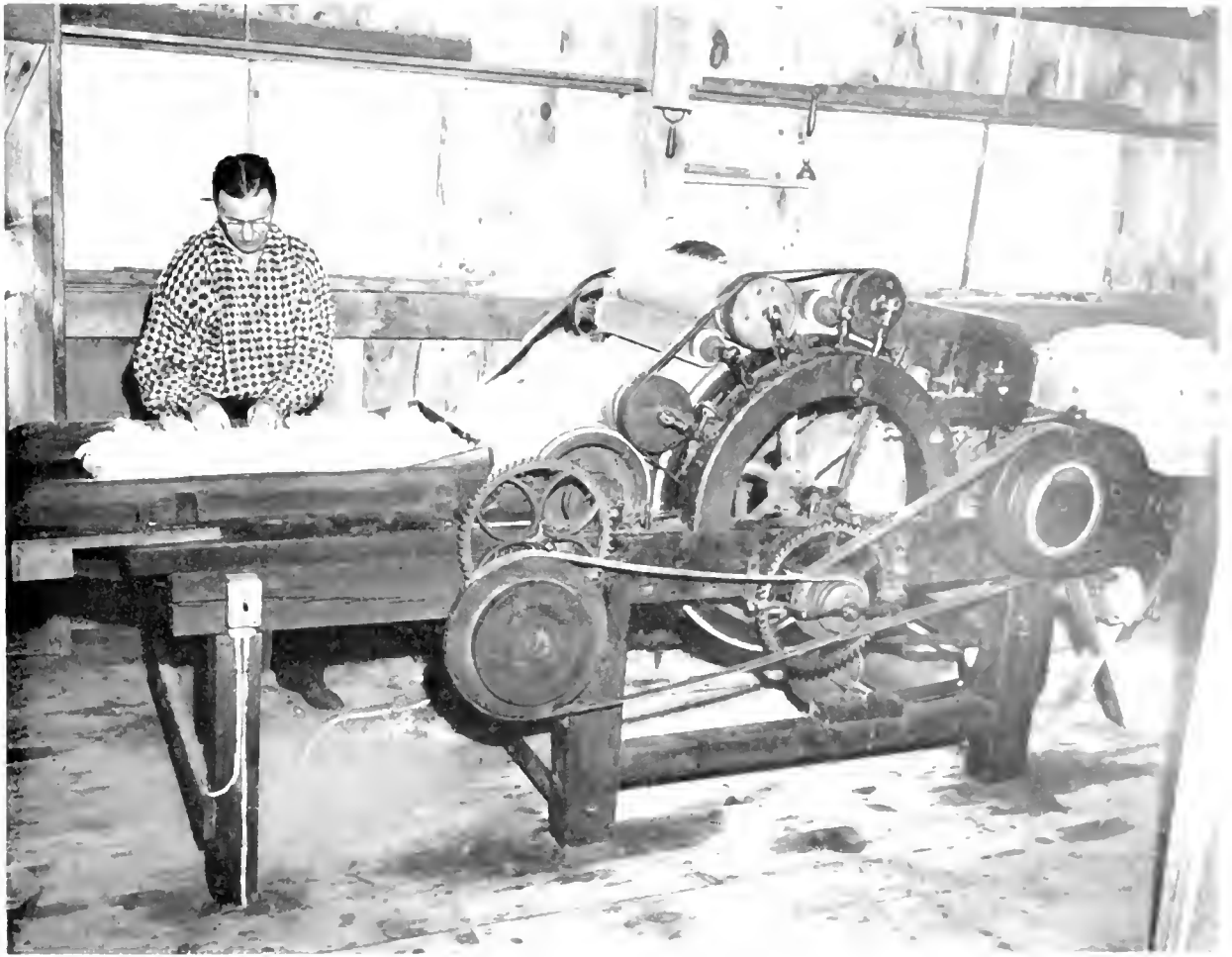


FIGURE 10. AN ORIGINAL SCHOLFIELD WOOL-CARDING MACHINE AT OLD STURBRIDGE VILLAGE, STURBRIDGE, MASSACHUSETTS. IT IS NOW RUN BY ELECTRICITY. *Photo courtesy of Old Sturbridge Village.*

the mill was purchased at a Sheriff's sale by Gorham Parsons, who sold a part interest to Paul Moody, a machinist from the textile town of Lowell. Moody operated the mill for the next 5 years and at his death in 1831 his heirs sold their interest back to Parsons. In 1832 it was leased for 7 years by William N. Cleveland and Solomon Wilde under the name of William N. Cleveland & Co. Following the expiration of the lease in 1839, a portion of the mill was occupied for 3 or 4 years by Enoch Pearson, believed to have been a descendant of the John Pearson who had been a clothier in Rowley in 1643, and subsequently various industries occupied other portions and later the entire building, which burned with all its contents on October 29, 1859.

If the first Scholfield carding machine remained a

part of the property, therefore it must have been lost in that fire. However, the Scholfields' importance to American wool manufacture was not contingent on the building of one successful carding machine, regardless of whether it was the first. It was the change in the scope of their business ventures after their move to Connecticut that synonymized the name of Scholfield with mechanical wool carding in America.

John and Arthur had built their woolen mill at Uncasville, a village in the town of Montville, and there Arthur remained with his brother until 1801, when he married, sold his interest to John, and moved to Pittsfield, Massachusetts. John and his sons continued to operate the mill until 1806, when difficulties over water privileges spurred him to purchase property in Stonington, Connecticut, where he built

new mill containing two double-cylinder carding machines.¹¹ In 1813, leaving one son in charge at Stonington, John returned to Montville and purchased another factory and water privileges. He continued in the woolen manufacture until his death in 1820.

Arthur, soon after arriving in Pittsfield, constructed a carding machine and opened a Pittsfield mill. The following advertisement appeared in the *Pittsfield Sun*, November 2, 1801:

Arthur Scholfield respectfully informs the inhabitants of Pittsfield and the neighboring towns, that he has a carding-machine half a mile west of the meeting-house, where they may have their wool carded into rolls for 12½ cents per pound; mixed 15½ cents per pound. If they find the grease, and pick and grease it, it will be 10 cents per pound, and 12½ cents mixed. They are requested to send their wool in sheets as they will serve to bind up the rolls when done. Also a small amount of woolens for sale.

The people around Pittsfield soon realized that the mechanically carded wool was not only much easier to spin but enabled them to produce twice as much yarn from the same amount of wool. Although many brought their wool to be carded at his factory, Arthur was not without problems. These were evident in his advertisement of May 1802, in which he stated that if the wool was not properly "sorted, clipped, and cleansed" he would charge an extra penny per pound. He also added that he would issue no credit. Shortly after this, recognizing the need for additional carding machines in other localities, Arthur Scholfield undertook the work of manufacturing such machines for sale. Through this venture he was to spread his knowledge of mechanical wool carding throughout the country.

The Scholfield Machines

The first record of Arthur's sale of carding machines appeared in the *Pittsfield Sun* in September 1803. The next year, in May 1804, his advertisement informed the readers that A. Scholfield continued to card wool, and also that:

He has carding-machines for sale, built under his immediate inspection, upon a new and improved plan, which he is determined to sell on the most liberal terms, and will give gratis and other instructions to those who wish to build for themselves, and cautions all whom it may concern to

¹¹ There is no record of the carding machine made of machinery which John had reported had been transferred to the Stonington mill.

beware how they are imposed upon by uninformed speculating companies, who demand more than twice as much for machines as they are really worth.

Scholfield must have felt that some of his competitors were charging much more for their carding machines than they were worth. Also, others were producing inferior machines that did not card the wool properly. Both factors encouraged Arthur to continue the commercial production of wool-carding machines. In April 1805 he again advertised:

Good news for farmers, only eight cents per pound for picking, greasing, and carding white wool, and twelve and a half cents for mixed. For sale, Double Carding-machines, upon a new and improved plan, good and cheap.

And in 1806:

Double carding machines, made and sold by A. Scholfield for \$253 each, without the cards, or \$400 including the cards. Picking machines at \$30 each. Wool carded on the same terms as last year, viz.: eight cents per pound for white, and twelve and a half cents for mixed, no credit given.

With both carpenters and machinists working under his direction, he soon abandoned completely the carding of wool and devoted his full time to producing carding machines. An advertisement in the *Pittsfield Sun* shows Alexander and Elisha Ely providing carding service there with a Scholfield machine in 1806. Scholfield machines were also set up in Massachusetts at Bethuel Baker, Jr., & Co. in Lanesborough in 1805, at Walker & Worthington in Lenox, at Curtis's Mills in Stockbridge, at Reuben Judd & Co. in Williamstown, in Lee at the falls near the forge, at Bairds' Mills in Bethlehem in 1806, and by John Hart in Cheshire in 1807. Subsequently many more Scholfield machines were set up in many other places as far away as Manchester, New Hampshire, in 1809 and Mason Village, New Hampshire, in about 1810.

One of the difficulties that Arthur encountered in building these early machines was in cutting the comb plates that freed the carded fleece from the cylinder. These plates had to be prepared by hand, the teeth being cut and filed one by one. In 1814 James Standing, an old friend and co-worker, smuggled into this country a "teeth-cutting machine," which he had procured on a trip to England.¹² Standing kept the machine closely guarded, permitting

¹² This is probably the machine that gave rise to stories of a carding machine having been smuggled from England during the early Byfield days. J. L. A. Smith, *The history of Pittsfield, Massachusetts, from the year 1800 to the year 1876*, Springfield, 1876, p. 167.

only Scholfield and one other friend to see it. Standing used his machine to make new saws of all descriptions and to re-cut old ones as well as to prepare comb plates for the carding machines. But in spite of this new simplified method of producing comb plates Scholfield's business did not flourish, for the tremendous influx of foreign fabrics after the War of 1812 greatly damaged the domestic textile industries, including the manufacture of carding machines.

By 1818 Scholfield's friends had persuaded him to apply to Congress for relief. To his brother John on April 20, 1818, he wrote:

. . . I have been advised by my friends to apply to Congress by a petition as we were the first that introduced the woolen Business by Machinery in this country and should that plan be adopted I have but little hopes of success but they say if it does no good it wont doo any harm but at any rate I should like your opinion and advice about it. . . .

Apparently John felt the plan would not succeed, for on the following December 17 Arthur wrote him again:

. . . With regard to applying to Congress I have given that up for I am of your opinion that it won't succeed what gave me some hopes I was advis'd to it by a member of the Senet who is a very influential man in Congress but he is now out and I think tis best to drop it. . . .

Arthur never applied to Congress for the recognition his contemporaries felt he deserved.¹³

Several changes in the construction of wool-carding machines took place during this period. As early as 1816 John Scholfield, Jr., was reported to have in his mill in Jewett City, Connecticut, a double-cylinder carding machine 3 feet wide. And in 1822 a Worcester, Massachusetts, machine maker advertised that he was "constructing carding machines entirely of iron."¹⁴ Although a few of these iron carding machines were sold, they did not become common until 50 years later.¹⁵

There is no record that Arthur Scholfield manufactured carding machines of a width greater than 24 inches, or entirely of iron. However, little is known of his last business years except that he remained in Pittsfield until his death, March 27, 1827.

¹³ U. S., 15th Congress, 1st and 2nd sessions, *The debates and proceedings in the Congress*, vols. for 1817-1819 (2).

¹⁴ *Worcester Spy*, July 10, 1822.

¹⁵ A natural delay. Although the cylinders and the card clothing wore out and had to be replaced, the heavy wooden frames of the early machines remained long in serviceable condition.

Only three wool-carding machines attributed to the hands of the Scholfields are known to exist today. All are 24-inch, single-cylinder carding machines of the same general description (see fig. 8). They differ only in minor respects that probably result from subsequent changes and additions. One (fig. 9), now located in the Plymouth Carding House, at Greenfield Village, Dearborn, Michigan, was discovered in Ware, Massachusetts. Another (fig. 10), now at Old Sturbridge Village, Sturbridge, Massachusetts,¹⁶ was uncovered in a barn in northern New Hampshire. The third (fig. 1), is in the U. S. National Museum in the collection of the Division of Textiles.

Both it and the Dearborn machine have in former times been described as "the original Scholfield woolen card." It is a romantic but unsubstantiated idea that either of these is the first Scholfield carding machine set up in the Byfield factory in 1794. The author's opinion is that all three were built by Arthur Scholfield during his years in the Pittsfield factory. Examination of the National Museum machine supports this opinion. The woods used are all native to the New England region. The frame, the large cylinder and the roller called the fancy are constructed of eastern white pine (the Sturbridge machine is also constructed principally of pine). The joints of the main frame are mortised and tenoned. At the doffing end the main frame and cross supports are numbered and matched, I to III, and at the feed end they are numbered V to VIII but were mis-matched in the original assembly. Further rigidity is achieved by means of hand-forged lag screws. The arch of the frame is birch and the arch arm maple. The 14-inch doffer roller is made of chestnut.¹⁷ The iron shafts are square and turned down at the bearings. The worker rollers are fitted with sprockets and turned by a hand-forged chain. The comb plate, stamped "Standing," is hand filed, and is undoubtedly one of those made before the "teeth-cutting machine" was smuggled from England, for although one-third of the plate is quite regular, the size and pitch of the teeth in the remaining two-thirds are irregular. Part of this irregularity might be explained as having been caused by the hand-sharpening of a plate originally cut by machine, but the teeth in one 2-inch span not

¹⁶ Once again in use, it is now powered by electricity. A pound of slivers from it (about 260) may be purchased for \$3.00.

¹⁷ The author is indebted to William N. Watkins, U. S. National Museum Curator of Agriculture and Wood Products, Smithsonian Institution, for the identification of the woods in the specimen.

only vary in size but have a pitch that would have been impossible to produce after the original plate had been made.¹⁷

There is no doubt that this carding machine was made by Arthur Scholfield, or under his immediate supervision, sometime between 1803 and 1814. It may well be one of the machines sent to southern New Hampshire in 1809 or 1810, as it is known to have been run in Nashua and Jethrey, New Hampshire, in the 1820's and 1830's, after which it was run by James Townsend in Marlboro, New Hampshire, from 1837 until 1890, when it was exhibited at the Mechanics Fair in Boston. Mr. Rufus S. Frost purchased the machine and owned it until his death in 1897. When the Frost estate was settled, the old Scholfield wool-

¹⁷The author is indebted to Mr. Don Berkebile of the Smithsonian's U. S. National Museum staff for his examination of the metal teeth on the comb plate of this machine.

carding machine was purchased by the Davis & Furber Machine Co., by which in 1954 it was presented to the National Museum.

The disappearance of the original Scholfield carding machine is regrettable, but fortunately the Scholfields' importance to the American woolen industry does not depend on their having produced this one machine. These brothers, arriving here at a critical time in our nation's history, made important contributions to our economic and to our technological progress - John by his mill operations, Arthur by his ultimate work of constructing wool-carding machines for sale. Of these two aspects, it is the contribution of Arthur that has had the more far-reaching effect, for he spread his expert knowledge of mechanical wool carding, in the form of machines, throughout the New England woolen centers. His machines now stand as monuments to the work of both.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:
PAPER 2

JOHN DEERE'S STEEL PLOW

Edward C. Kendall

DEERE AND ANDRUS	17
THE FIRST FLOW	
STEEL OR IRON	
WHY A STEEL FLOW	
RECONSTRUCTIONS	24
IN SUMMARY	25

JOHN DEERE'S STEEL PLOW

John Deere in 1837 invented a plow that could be used successfully in the sticky, root-filled soil of the prairie. It was called a steel plow. Actually, it appears that only the cutting edge, the share, on the first Deere plows was steel. The moldboard was smoothly ground wrought iron.

Deere's invention succeeded because, as the durable steel share of the plow cut through the heavy earth, the sticky soil could find no place to cling on its polished surface.

AMERICANS MOVING WESTWARD in the beginning of the 19th century soon encountered the prairie lands of what we now call the Middle West. The dark fertile soils promised great rewards to the farmers settling in these regions, but also posed certain problems. First was the breaking of the tough prairie sod. The naturalist John Muir describes the conditions facing prairie farmers when he was a boy in the early 1850's as he tells of the use of the big prairie-breaker plows in the following words:¹

They were used only for the first ploughing, in breaking the wild sod woven into a rough mass, chiefly by the root-like roots of perennial grasses, reinforced by the tap roots of oak and hickory bushes, called "grubs," some of which were more than a century old and four or five inches in diameter. . . . It in good time, the plough cut through and turned over these grubs as if the century-old wood were the flesh of carrots and turnips; but if not in good time, the grubs promptly tossed the plough out of the

factor in prairie plowing that farmers in these regions carried a wooden paddle solely for cleaning off the moldboard, a task which had to be repeated so frequently that it seriously interfered with plowing efficiency. It seems probable that by the 1830's blacksmiths in the prairie country were beginning to solve the problem of continuous cultivation of sticky prairie soil by nailing strips of saw steel to the face of wooden moldboard of the traditional plows. Figure 1 is a photograph of an 18th century New England plow in the collection of the U. S. National Museum. This is one type of plow which was brought west by the settlers. It contributed to the development of the prairie breaker shown in figure 2. The first plow on record with strips of steel on the moldboard is attributed to John Lane in Chicago in 1833.² Steel presented a smoother surface which shed the sticky loam better than the conventional wooden moldboards covered with wrought iron, or the cast iron moldboards of the newer factory-made plows then coming into use.

It is generally accepted as historical fact that John Deere made his first steel plow in 1837 at Grand Detour, Illinois. The details of the construction of

¹ John Muir, *My First Days on the Prairie*, ed. by John Muir, Jr. (New York: The Century Company, 1907), p. 10.

² R. E. Andrey, *Tools in agriculture implements*, Chicago, 1894, p. 14.

THE AUTHOR:

Edward C. Kendall is curator of agriculture, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.

this plow have been variously given by different writers. Ardrey³ and Davidson⁴ describe Deere's original plow as having a wooden moldboard covered with strips of steel cut from a saw, in the manner of the John Lane plow.

In recent years the 1837 Deere plow has been pictured quite differently. This has apparently come about as the result of the discovery of an old plow identified as one made by John Deere at Grand

plows manufactured by Deere in the 1840's.⁵ The Company states that according to its records, this was one of three plows made by Deere in 1838 and that it was probably substantially identical with the first one made in 1837.⁶ It may be difficult to prove that the Museum's specimen was made in 1838, but a comparison of this plow (fig. 7) with the 1847 mold-board (fig. 5) and the 1855 plow (fig. 6) suggests that the Museum's plow is the earliest of the three, since there is particularly evident an evolution of the shape of the moldboard from a simple, almost crude form to a more sophisticated shape.

DEERE AND ANDRUS

Writers of the 20th century describing the making of the first John Deere steel plow have in mind the

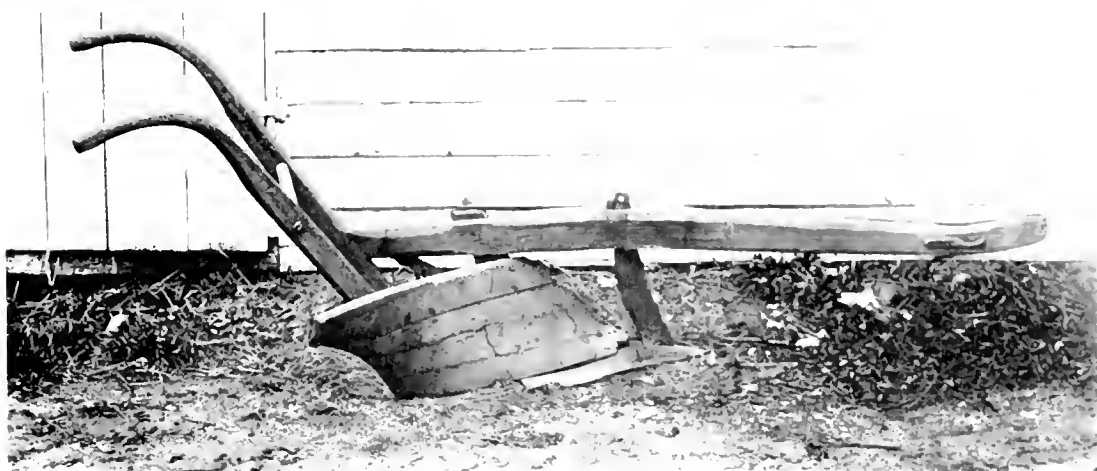


Figure 1. NEW ENGLAND STRONG PLOW, MID-18TH CENTURY. Colter locked into heavy, broad share; wooden moldboard covered with iron strips. (Cat. no. F1061; Smithsonian photo 13214.)

Detour in 1838 and sold to Joseph Brierton from whose farm it was obtained in 1901 by the maker's son, Charles H. Deere. He brought it to the office of Deere & Company at Moline, Illinois, for preservation and display. This plow is shown in figures 7 and 9. In 1938 Deere & Company presented it to the U. S. National Museum, where it is on display. It can be seen that the moldboard is made of one curved diamond-shaped metal slab. This plow bottom conforms to the description of the "diamond"

1838 plow. One⁷ has John Deere pondering the local plowing problem and getting an idea from the polished surface of a broken steel mill saw. Another⁸ claims that Leonard Andrus, the founder and leading figure of Grand Detour and part owner of the sawmill,

³ Leo Rogin, *The evolution of an American invention: the plow and its place in the agricultural life of the United States from the nineteenth century* (Berkeley, 1951), p. 35.

⁴ U. S. National Museum records under accession 14894.

⁵ Neil M. Clark, *The Deere* (Moline, 1937), pp. 34, 35.

⁶ Stewart H. Holbrook, *Machinery in Iowa* (New York, 1955), pp. 178, 179. To an inquiry by this author, Mr. Holbrook replied that most if not all of the material about Andrus came from the files of the I. I. Case Company.

³ *Ibid.*, p. 16.

⁴ J. B. Davidson, "Village machinery," in I. H. Bailey's *Cyclopedia of American agriculture* (New York, 1907), vol. 1, p. 389.

conceived the design of the plow and employed Deere, the blacksmith newly arrived from Vermont, to build it. This idea may have originated with and was certainly promoted by the late Fred A. Wirt, as advertising manager of the J. I. Case Company. It is difficult, at this distance, to determine the parts played at the beginning by Deere and Andrus.

The earliest existing partnership agreement involving Andrus and Deere is dated March 20, 1843.⁹ The existing copy is unsigned, but its conditions are the same as those in the agreements executed during the next few years. It began by stating that Deere and Andrus had agreed "to become copartners together

which brought in a third partner, Horace Paine, described the business as "the art and trade of Blacksmithing Plough Making Iron Castings and all things thereto belonging . . ." and stated that the copartnership should be conducted "under the name and firm of L. Andrus and Co." The third agreement, dated October 20, 1846, in which another man appeared in place of Paine, gave the name of the firm as Andrus, Deere, and Lathrop.¹¹ This carried an addendum dated June 22, 1847, in which Andrus and Deere bought out Lathrop's interest in the business and agreed to continue under the name of Andrus and Deere. This is the only mention of the firm of Andrus and Deere. It could only have lasted a few months because it was in 1847 that Deere moved to Moline and established his plow factory there.

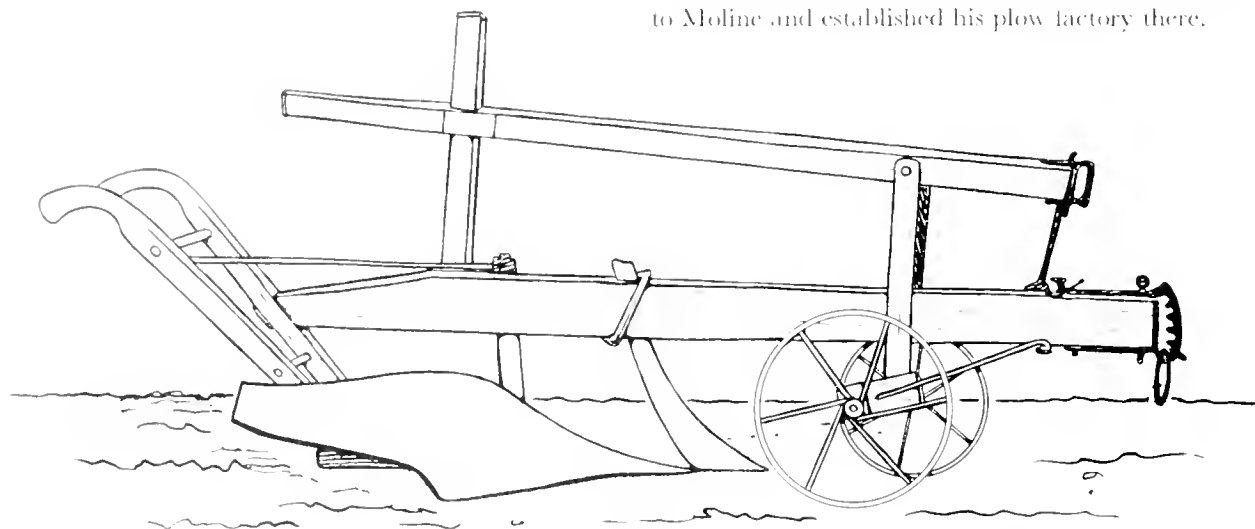


Figure 2. LARGE PRAIRIE-BREAKING PLOW, MID-19TH CENTURY. Wheels underneath the beam regulate the depth of plowing; large wheel runs in the furrow, small wheel on the land. The colter is braced at the bottom as well as at the top. The share cuts a broad, shallow strip of sod which the long, gently curving moldboard turns over unbroken.

in the art and trade of Blacksmithing, ploughmaking and all things thereto belonging at the said Grand Detour, and all other business that the said parties may hereafter deem necessary for their mutual interest and benefit . . ." One of the terms was that the copartnership should continue from the date of the agreement "under the name and firm of Leonard A. & Co."

A second agreement dated October 26, 1844,¹⁰

These agreements suggest that Leonard Andrus was the capitalist of the young community of Grand Detour, as well as its founder. The dominance of the name Andrus tends to back up the opinion which holds that Andrus was the leading figure in the development of the successful prairie plow. On the other hand, the general tone of the agreements suggests that two or more people were participating in an enterprise in which each contributed to the business and shared in the results. Deere contributed his plow and his blacksmith shop, tools, and outbuildings;

¹¹ *Ibid.*, p. 2.



Figure 3.—RECONSTRUCTIONS OF JOHN DEERE'S 1837 PLOW. For a discussion of the position and attachment of the handles see p.24. (*Deere & Company photo.*)

Andrus contributed money and business experience. There is no indication that they were formally associated prior to the agreement of March 20, 1843. An advertisement (it is quoted later) dated February 3, 1843, and appearing in the March 10, 1843, issue of the *Rock River Register*, carries an announcement by John Deere that he is ready to fill orders for plows, which he then describes. There is no mention of Andrus or of an Andrus and Deere firm. I am inclined by the evidence to the view that Deere worked out his plow by himself, began to manufacture it in small numbers, needed money to enlarge and expand his operations, and went to the logical source of capital in the community, Leonard Andrus.

In support of this view I quote a statement by Mr. Burton F. Peck¹² who has spent most of his life in Deere & Company and who may now be the only person living who knew John Deere:

Andrus removed to Grand de Tour from some place in New York [Rochester, though originally from Vermont]. Some years later John Deere came along from Rutland, Vermont leaving his family behind him. Whether Deere ever heard of Andrus or Andrus of Deere no one knows.

Having decided to remain in Grand de Tour, Deere sent for his family asking my paternal grandfather, William Peck, to bring them and also the Peck family out to Grand de Tour. This was done via covered wagon the journey occupying some six weeks. My father, Henry C. Peck, was then an infant age six weeks and Charles Deere, the son of John, an infant of about the same age. Of course these infants came along sleeping in the feed box of the wagon. My grandfather "took up land" adjacent to Grand de Tour and John Deere continued in the manufacturing business.



Incidentally, John Deere and William Peck were brothers-in-law having married sisters and what I have said, and much more that I might say to you, is based upon what I have been told by my grandfather, by John Deere and by others who had a part in the early history of the company. So far as I know, I am the only living person who ever knew or saw John Deere.

... I joined the Deere Company on October 1, 1833, at the age of 16 and retired on the 28th of April, 1979—nearly 68 years. C. H. Deere was my great friend and benefactor. I was educated at his expense as a lawyer and practiced for thirteen years. During this time I was his personal attorney, I drew his will, was made trustee thereunder, and probably was more intimate with him than any living person. I have seen and read the manuscript of an early history of the company which he wrote, but never published and there was nothing in it to indicate that Andrus had any part in the manufacture of the first successful steel plow and it is my firm belief that he had no part other than perhaps a friendly interest in it.

THE FIRST PLOW

Most writers describe Deere cutting a diamond-shaped piece out of a broken steel mill saw. There is usually no further identification of the type of saw beyond the statement that it came from the Andrus sawmill. Neil Clark, author of a brief biography of John Deere, states that the diamond-shaped piece was cut out of a circular saw.¹³ There is no evidence given to support this. There are some powerful arguments against it. The circular saw, especially of the larger size, was probably not very common in America in the 1830's. Although an English patent for a circular saw was issued in 1777 the first circular saw in America is attributed to Benjamin Cummings of Bentonsville, New York, about 1814.¹⁴

In a small, new, pioneering community it is unlikely that the local sawmill would have been equipped with the newer circular saw rather than the traditional and older saw which remained in use.

¹² Letter from Burton F. Peck to M. E. Putnam, December 18, 1957, in U. S. National Museum records under accession 148904.

¹³ Clark, *op. cit.* note 1, p. 75.
¹⁴ C. H. Knapp, *op. cit.* note 1, p. 10.
¹⁵ Clark, *op. cit.* note 1, p. 29.

throughout the 19th century and, in places, well into the 20th century. The up and down saw was a broad strip of iron or steel with large teeth in one edge. Driven by water power it slowly cut large logs into boards. It is doubtful that the circular saws of that period were large enough for this kind of mill work. The second argument is the shape of the mold-

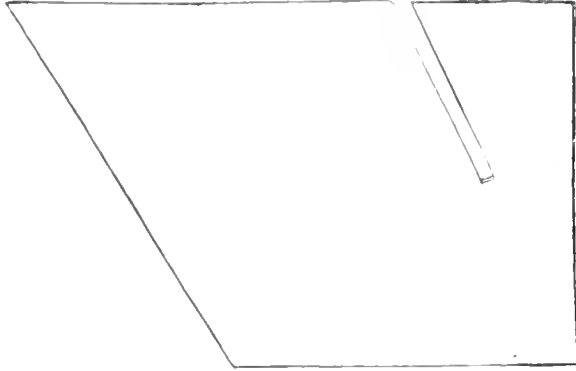


Figure 1. How DEERE PROBABLY CUT AND BENT THE FLAT PATTERN of his 1838 plow to form the moldboard and landside. Because of the shape of the moldboard it became known as the diamond plow,

board itself. The photograph of the 1838 plow in Deere¹⁴ shows that the shape of the moldboard is unconventional. It is essentially a parallelogram curved to present a concave surface to the furrow face and thus to make a simple, small but workable plow. A parallelogram or diamond would be an

easy shape to cut out of a mill saw with the teeth removed. The moldboard on the 1838 plow is from .228 to .238 inches thick and its width is 12 inches. These dimensions approximate those given in an 1897 Disston catalog¹⁵ which describes mulay saws, a type of mill saw, from 10 to 12 inches wide and from 4 to 9 gauge. Gauge number 4 is the thickest and is .238 inches.

Examination of the 1838 plow suggests that Deere cut the moldboard and landside as one piece, which



Figure 5. MOLDBOARD OF 1847 JOHN DEERE PLOW, showing how the diamond shape of the original design has been slightly modified. (Deere & Company photo 57102-D.)

was then heated and bent to the desired form. The pattern of this piece is shown in figure 4. Some additional metal appears to be forged into the sharp bend at the junction of the moldboard and the landside apparently to strengthen this part, which may have begun to open during the bending. If, however, Deere had used a large circular saw with plenty of room for cutting out a moldboard of the usual shape and size, it seems likely that he would have made a plow of more conventional appearance. In any event his moldboard of one jointless piece of polished metal would scour better than one of wood covered with strips of steel since the nailheads and the joints between the strips would provide places for the earth to stick.

¹⁵ Henry Disston & Sons, *Punchist*, Philadelphia, 1897, p. 28.

STEEL OR IRON

A very great majority of writers describing John Deere and his plow attribute his fame to his development of a successful steel plow which made cultivation of rich prairie soil practical. The emphasis is always

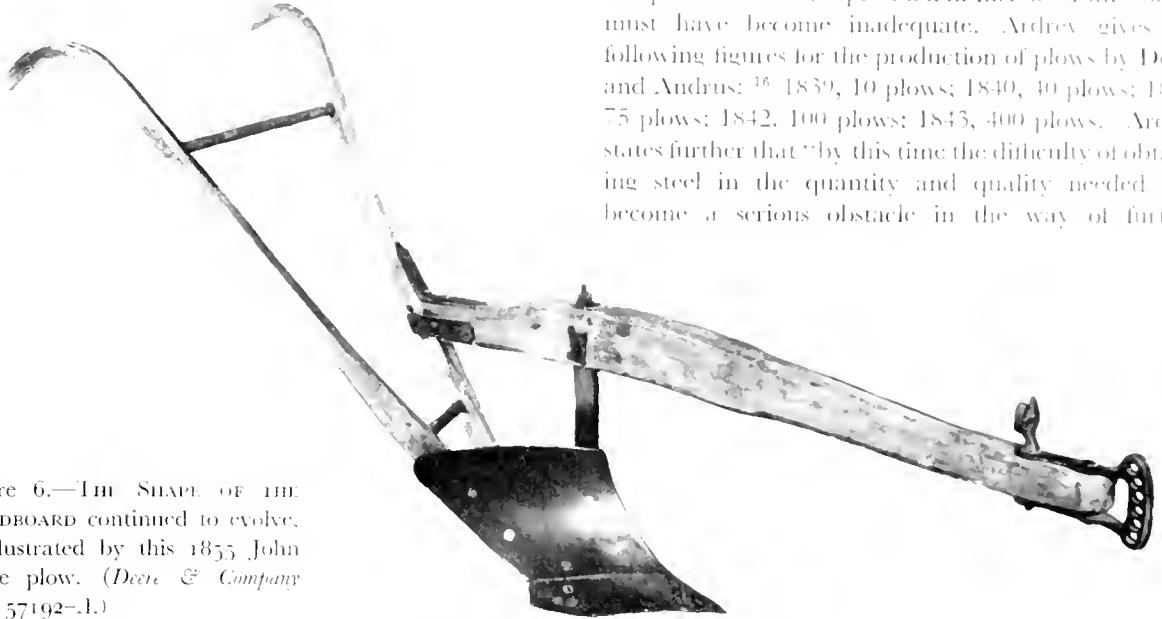


Figure 6.—THE SHAPE OF THE MOLDBOARD continued to evolve, as illustrated by this 1855 John Deere plow. (*Deere & Company photo 57192-1.*)

on the development of a steel moldboard and the assumption is that from the 1837 plow onward stretched an unbroken line of steel moldboard plows. An advertisement for John Deere plows in the March 10, 1843, issue of the *Rock River Register*, published weekly in Grand Detour, Illinois, gives a detailed description, here presented in full:

John Deere respectfully informs his friends and customers, the agricultural community, of this and adjoining counties, and dealers in Ploughs, that he is now prepared to fill orders for the same on presentation.

The Moldboard of this well, and so favorably known PLOUGH, is made of wrought iron, and the share of steel, $\frac{5}{16}$ of an inch thick, which carries a fine sharp edge. The whole face of the moldboard and share is ground smooth, so that it scours perfectly bright in any soil, and will not choke in the foulest of ground. It will do more work in a day, and do it much better and with less labor, to both team and holder, than the ordinary ploughs that do not scour, and in consequence of the ground being better prepared, the agriculturalist obtains a much heavier crop.

The price of Ploughs, in consequence of hard times, will be reduced from last year's prices. Grand Detour, Feb. 3, 1843.

This raised two questions: Why, and for how long, was wrought iron used for the moldboards of the Deere plows? Of what material is the moldboard of the 1838 plow made? During the first few years, when production was very small, there were probably enough worn out mill saws available for the relatively few plows made. As production increased this source must have become inadequate. Ardrey gives the following figures for the production of plows by Deere and Andrus: ²⁵ 1839, 10 plows; 1840, 40 plows; 1841, 75 plows; 1842, 100 plows; 1843, 400 plows. Ardrey states further that "by this time the difficulty of obtaining steel in the quantity and quality needed had become a serious obstacle in the way of further

development." The statement, quoted above, that the moldboard was of wrought iron and the statistics on production of plows during the 1840's and 1850's belie Ardrey's claim that it was a serious obstacle, nor is there any suggestion in the advertisement that wrought iron was being substituted for steel.

In 1847 John Deere amicably severed relations with the firm of Andrus & Deere and moved to Moline, Illinois, to continue plow manufacturing in a site that had better transportation facilities than Grand Detour. The new firm produced 700 plows in the first year, 1600 in 1850, and 10,000 in 1857.²⁶ Swank²⁷ states that the first slab of cast plow steel ever rolled in the United States was in 1846 and that it was shipped to John Deere of Moline, Illinois. A little later he says that it was not until the early 1860's in this country that several firms succeeded in making

²⁵ Ardrey, *loc. cit.*, footnote 23, p. 19.

²⁶ *Ibid.*, p. 166.

²⁷ James M. Swank, *History of the Plow*, Philadelphia, 1892, pp. 89, 90.

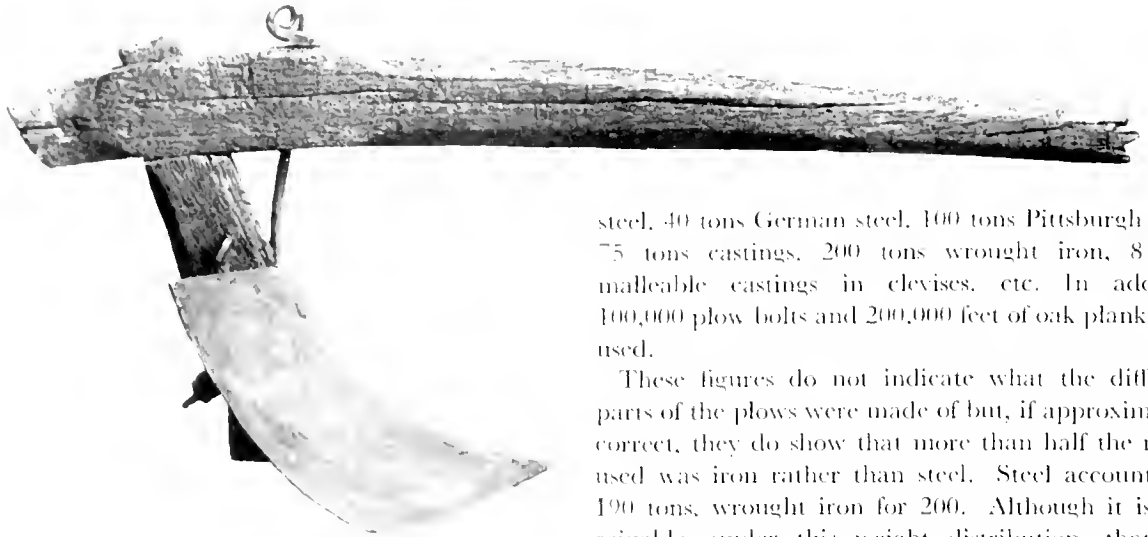


Figure 7. JOHN DEERE'S 1838 Plow, RIGHT SIDE, showing large iron staple used to fasten end of right handle to the standard. Note remains of wooden pin near rear end of plow beam. (Cit. no. F1111; Smithsonian photo 42639 .1.)

high grade crucible cast steel of uniform quality as a regular product.

Based on a visit to Deere's factory in 1857 the *Country Gentleman*¹⁹ gave the yearly output as 13,400 plows. It pictured four of seven models and stated, "these are all made of cast steel, and perfectly polished before they are sent out, and are kept bright by use, so that no soil adheres to them." The article then gives the tonnages of iron and steel used by the Deere factory in a year. They are as follows: 50 tons cast

¹⁹ *Country Gentleman*, 1857, vol. 10, p. 129.

steel, 40 tons German steel, 100 tons Pittsburgh steel, 75 tons castings, 200 tons wrought iron, 8 tons malleable castings in clevises, etc. In addition 100,000 plow bolts and 200,000 feet of oak plank were used.

These figures do not indicate what the different parts of the plows were made of but, if approximately correct, they do show that more than half the metal used was iron rather than steel. Steel accounts for 190 tons, wrought iron for 200. Although it is conceivable, under this weight distribution, that the shares and moldboards were made of steel while the landsides and standards were made of wrought iron, other distributions are also possible, and it is quite conceivable that at this period some of the plows had steel moldboards while others had wrought-iron ones. An analysis of the metal in different parts of an 1855 John Deere plow, now at the factory in Moline, may shed some light on this, but from these figures and dates it seems likely that most of John Deere's plows during the 1840's and 1850's had wrought-iron moldboards with steel shares. (It should be borne in mind that the poorer grades of steel available at this time were probably no more satisfactory than cast iron as far as scouring clean in sticky soil was concerned.)

The question of the material in the moldboard of the 1838 plow was answered when a spark-test analysis was made of the metal in the moldboard and share. In this test the color, shape, and pattern of the spark bursts produced by a high-speed grinding wheel indicate the type of iron or steel. Several spots along the edges and back surface of the moldboard were tested.

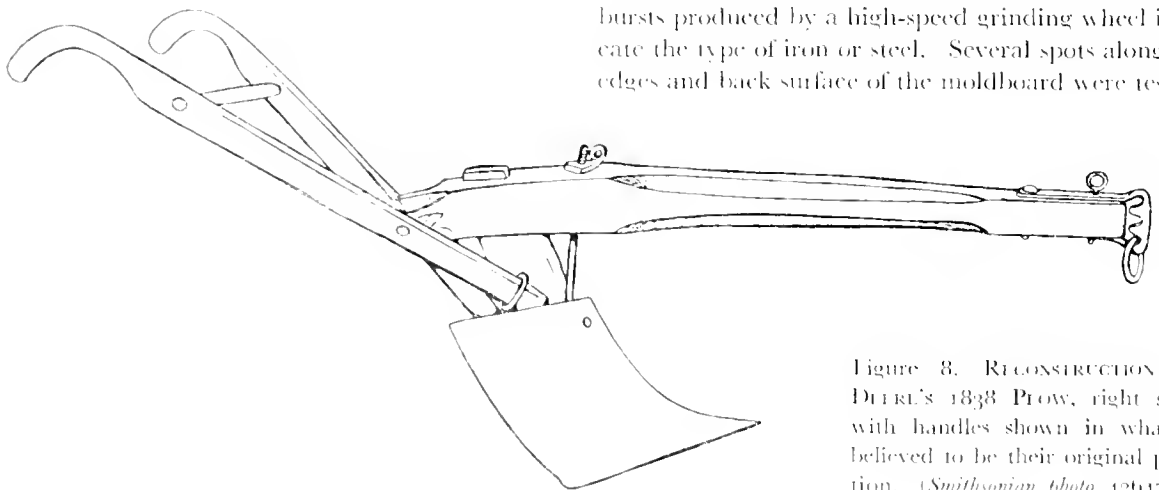


Figure 8. RECONSTRUCTION OF DEERE'S 1838 Plow, right side, with handles shown in what is believed to be their original position. (Smithsonian photo 42647.)

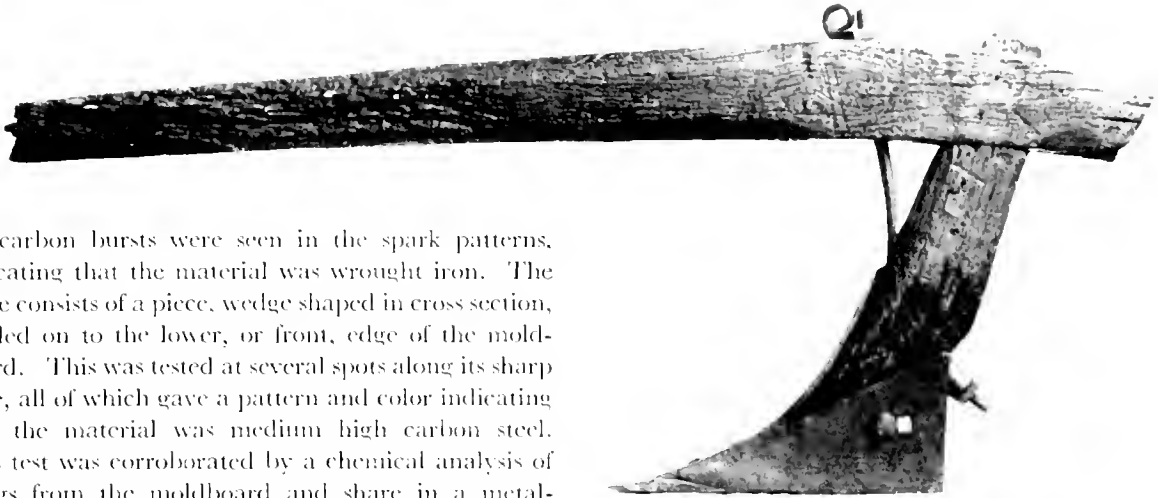


Figure 9.—JOHN DEERE'S 1838 PLOW, LEFT SIDE, showing details of construction and relationship of landside to moldboard. (Cat. no. F1111; Smithsonian photo 42634.)

No carbon bursts were seen in the spark patterns, indicating that the material was wrought iron. The share consists of a piece, wedge shaped in cross section, welded on to the lower, or front, edge of the moldboard. This was tested at several spots along its sharp edge, all of which gave a pattern and color indicating that the material was medium high carbon steel. This test was corroborated by a chemical analysis of filings from the moldboard and share in a metallurgical laboratory. A small trace of carbon was found in the moldboard. It may be present as the result of contamination from several sources, a likely one being the charcoal fire in the forge when it was heated for bending and shaping.²⁰

These tests agree perfectly with the description in the 1843 advertisement. It seems, therefore, that Deere's success in making plows that worked well in prairie bottom lands depended as much on the smooth surface he produced by grinding and polishing as on the material used.

The filing of the edge of the moldboard for the metallurgical test disclosed that the wrought-iron slab consisted of five thin laminations apparently forged together but with separations visible. The length and regularity of the lines of separation seem to preclude their being striations resulting from the fibrous structure of wrought iron. This calls into question the theory that the moldboard and landside were cut from a mill saw, since it hardly seems likely that a saw would be made of laminated material. The possibility exists that the body of the mill saw might have been made this way, with a tooth-bearing steel edge welded on, but there seems little reason for making a saw out of thin laminations. It is also possible that this laminated iron originally had been intended for some other purpose, such as boiler plate, and may have been available in rectangular pieces. In making the 1838 plow Deere followed a pattern (fig. 4), which suggests that he cut it out of such a piece.

²⁰ Reports on spark test by E. A. Battison, U. S. National Museum, and on metallurgical investigation by A. H. Valentine, Metallographic Laboratory of the Bethlehem Steel Company's Sparrows Point Plant.

Since the moldboard of the 1838 plow is of wrought iron, and since this plow is thought to be essentially identical with the first one Deere made in 1837, it is highly probable that the 1837 plow also had a wrought-iron moldboard, a condition which appears to have been the basic pattern for John Deere plows until the middle 1850's.

WHY A "STEEL" PLOW

In view of the facts and the probabilities based on them, how is the legend of the John Deere steel plow to be explained? There are several likely reasons. It is possible that the first plow, in 1837, was made from a broken steel mill saw. It is also possible that within a few years puddled iron came to be used for the moldboards because of the scarcity of suitable steel, either in the form of broken mill saws or as plates ordered from foundries in America (the high price of steel imported from England made this an impractical source). However, it seems more likely that it became known as a steel plow owing to the importance Deere attached to his plows having steel shares, as shown in his advertisement in 1843. A steel share, tougher than cast iron, would hold an edge much better than wrought iron, and John Muir's description of prairie plowing, quoted earlier, substantiates the importance of a tough, sharp share.

Deere's plows, probably distinctive by reason of their steel shares, may have been called "steel"

plows, in the regions where they were used, to distinguish them from the standard wooden plows and from the newer cast-iron implements. The term "wooden plow" has a similar history. For well over 2000 years in Europe some plows have been made with iron shares and the rest of the structure wood. Plows in 18th-century America were made principally of wood with iron shares, colters, and clevises, and with strips of iron frequently covering the wooden moldboard. These implements were called, simply, plows of various regional types. Not until the development and spread of the factory-made plows with cast-iron moldboards, landsides, and standards did the term "wooden plow" come into use to differentiate all these plows from the newer ones. Subsequently writers have been led to assume that "wooden plow" meant a plow with no iron parts and consequently to make unwarranted statements about the primitiveness of the 18th-century implements.

A second reason for use of the term "steel plow" may have developed from the supposition that the moldboards of the first John Deere plows were made of diamond-shaped sections cut from old mill saws, which later writers seem to have assumed were made of steel. (It is probable that from the late 1850's on Deere plows had steel moldboards.) However, mill saws of the early 19th century were not necessarily made of steel, which was then relatively expensive. I have been told of an old mill saw made of wrought iron on which was welded a steel edge that carried the teeth.²¹ Rees' *Cyclopaedia*²² describes saws as being made of either wrought iron or steel, the latter being preferable. Therefore, it seems most likely that Deere's plows, from his first until the middle 1850's were made with highly polished wrought-iron moldboards and steel shares.

RECONSTRUCTIONS

The remains of the 1838 plow are shown in figures 7 and 9. One's curiosity is aroused as to what the plow looked like in its original state, complete with handles. Several full-scale 3-dimensional reconstructions and a number of sketches of the 1837 plow have been made. The reconstructions all must have been based on the remains of the 1838 plow, since they

resemble it closely and it is the only surviving plow of this type known.

Recently I received a photograph (fig. 3, right) of a plow which has been boxed and in storage for many years at Deere & Company which may be an early Deere plow. As it appears in the photograph, the plow looks unconvincing. The handles are fastened by bolts and nuts, a manner uncommon in American plow making in the early 19th century. The shape of the handles is that of stock handles available for small plows and cultivators in such a catalog as Belknap's. The plow seems very high and weakly braced. There is no logical reason for curving the end of the beam down and cutting it off at a slant if the handles are attached in the manner shown. The edges of the tenon on the upper end of the standard where it goes through the mortise in the beam have been neatly beveled in a manner I have never seen before on any other plow. All of this leads me to think that this is an early reconstruction based on the remains of the 1838 plow which it only roughly approximates in proportion and design.

Another of these reconstructions is shown in figure 5, left. Although superficially like the 1838 plow it varies considerably in its proportions, in the angular relations of its parts, and in other details such as the use of iron bolts and nuts in place of wooden pins. All these reconstructions agree in one thing. They show a plow with handles fastened to both sides of the plow beam and standard.

During an examination of the 1838 plow it occurred to me that there was no indication of an attachment of a handle on the landside in the same manner as on the furrow side. The position and attachment of the handle in figure 7 is clearly indicated by the remains of a wooden pin in the side of the plow beam near the rear end and by the large iron staple, in the side of the standard, which must have held the tapered lower end of the handle. Figure 8 is a sketch showing this handle in position. The landside view of this plow in figure 9 shows that the pin did not extend through the beam nor are there marks on the standard to indicate the position of a staple like that on the furrow side. The four holes approximately in line on the standard and beam show where a piece of sheet metal had been nailed to hold the beam and standard in about the right position. The outline of the sheet metal can be seen on the side of the beam. This was removed at the time this examination was made.

²¹ For this information I am indebted to Mr. L. A. Battison of the U. S. National Museum staff.

²² Abraham Rees, *The Cyclopaedia or universal dictionary of arts, sciences, and literature*, Philadelphia, 1810-1842, vol. 33, under saw.

How was the landside handle attached? W. E. Bridges of the National Museum suggests that it might have been attached to the lower side of the standard and the rear end of the plow beam. This seems, beyond doubt, to be correct. The wood has deteriorated considerably over the years and the joints are loose, but, within the limits of the existing structure, the plow beam can easily be set in such a position that its sloping rear end lines up with the slope of the underside of the standard. Furthermore, a long bolt runs from the upper part of the moldboard through the standard and projects quite far beyond its lower surface, as can be seen in figure 7. The end of the bolt is threaded only part way and it has been necessary to put a cylindrical metal spacer on it in order to draw up the nut snugly. This long bolt must originally have passed through the lower end of the handle, which, in turn, was fastened to the end of the plow beam by a tenon on the end of the beam,

on the old plows: in the same plane. Symmetrical handles branching from both sides of the beam are found on cultivators, shovel plows, middle busters, and sidehill plows where the moldboard is turned alternately to each side.

IN SUMMARY—

The existing evidence, I believe, indicates that:

1. The successful prairie plow with a smooth one-piece moldboard and steel share was basically Deere's idea.
2. The moldboards of practically all of his plows,

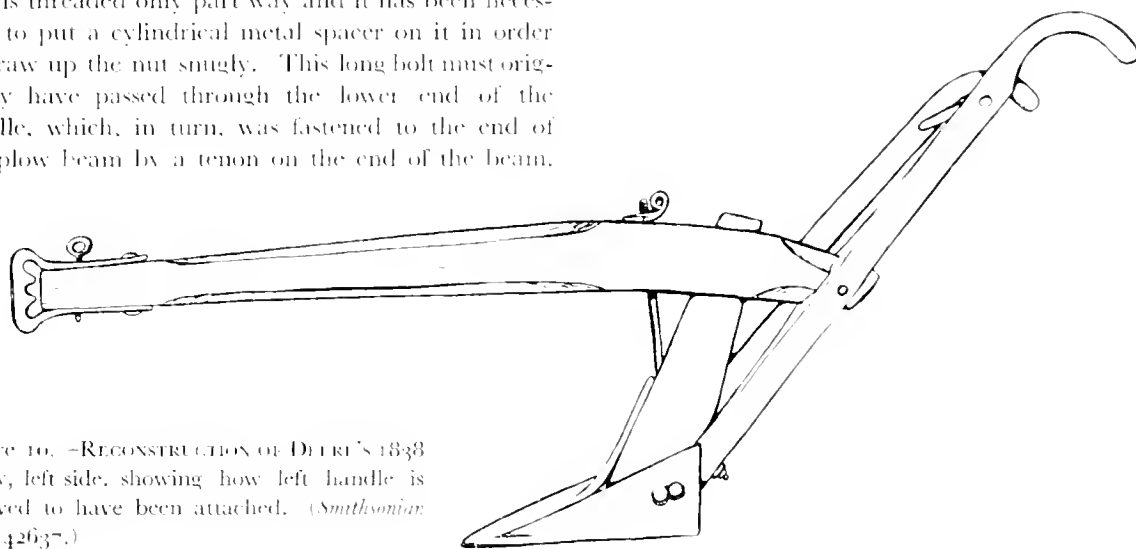


Figure 10. —RECONSTRUCTION OF DEERE'S 1838 Plow, left side, showing how left handle is believed to have been attached. (*Smithsonian photo 42637*.)

now broken off, passing through a mortise in the handle. This was the common method of fastening the handle to the beam. The square hole in the plow's iron landside (fig. 7), which at first might seem meant for another bolt passing through the lower end of the handle at right angles to the long bolt, seems too close to the other bolt and to the edges of the handle. It may simply be a first try for the bolt through the bottom of the standard. In this manner the handle would have been strongly attached to the plow frame and, at the same time, would have materially helped to make it rigid by forming one side of a triangular structure. Figures 3 and 10 show what I believe to be the correct reconstruction of the 1838 Deere plow along the lines just described and, therefore, the probable appearance of the 1837 plow.

It should also be noted that it was general practice in making fixed moldboard plows to have the plow beam, standard, handle, and landside (or sharebeam,

from 1837 and for about 15 years, were made of wrought iron rather than steel.

3. The success of his plows in the prairie soils depended on a steel share which held a sharp edge and a highly polished moldboard to which the sticky soils could not cling.

4. The importance attached to the steel share led to the plows being identified as steel plows.

5. The correct reconstruction of the 1838 plow, and, by inference, the 1837 plow, is shown in figures 8 and 10, previous reconstructions being wrong primarily in the position and attachment of the handles.

6. The Museum's John Deere plow (Cat. No. F1111), shown in figures 7 and 9, is a very early specimen, on the basis of a comparison of it with Deere moldboards of 1847 and 1855 and its conformity to Deere's description of his plows in an 1843 advertisement; and the 1838 date associated with it is plausible.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:
PAPER 3

THE BEGINNINGS OF CHEAP STEEL
Philip W. Bishop

STEEL BEFORE THE 1850'S	29
BESSEMER AND HIS COMPETITORS	30
ROBERT MUSHET	33
LEBBW VALE AND THE BESSEMER PROCESS	35
MUSHET AND BESSEMER	37
WILLIAM KELLY'S AIR-BOILING PROCESS	42
CONCLUSIONS	46

THE BEGINNINGS OF CHEAP STEEL

By Philip W. Bishop

Other inventors claimed a part in the invention of the Bessemer process of making steel. Here, the contemporary discussion in the technical press is re-examined to throw light on the relations of these various claimants to the iron and steel industry of their time, as having a possible connection with the antagonism shown by the ironmasters toward Bessemer's ideas.

THE AUTHOR: *Philip W. Bishop is curator of arts and manufactures, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.*

THE DEVELOPMENT of the world's productive resources during the 19th century, accelerated in general by major innovations in the field of power, transportation, and textiles, was retarded by the occurrence of certain bottlenecks. One of these affected the flow of suitable and economical raw materials to the machine tool and transportation industries: in spite of a rapid growth of iron production, the methods of making steel remained as they were in the previous century; and outputs remained negligible.

In the decade 1855-1865, this situation was completely changed in Great Britain and in Europe

generally; and when the United States emerged from the Civil War, that country found itself in a position to take advantage of the European innovations and to start a period of growth which, in the next 50 years, was to establish her as the world's largest producer of steel.

This study reviews the controversy as to the origin of the process which, for more than 35 years¹ pro-

¹ From 1870 through 1907, "Bessemer" production accounted for not less than 50 percent of United States steel production. From 1880 through 1895, 80 percent of all steel came from this source: Historical Statistics of the United States 1789-1945 (Washington, U. S. Department of Commerce, Bureau of the Census, 1949), Table J, 165-170 at p. 187.

vided the greater part of the steel production of the United States. It concerns four men for whom priority of invention in one or more aspects of the process has been claimed.

The process consists in forcing through molten cast iron, held in a vessel called a converter, a stream of cold air under pressure. The combination of the oxygen in the air with the silicon and carbon in the metal raises the temperature of the latter in a spectacular way and after "blowing" for a certain period, eliminates the carbon from the metal. Since steel of various qualities demands the inclusion of from 0.15 to 1.70 percent of carbon, the blow has to be terminated before the elimination of the whole carbon content; or if the carbon content has been eliminated the appropriate percentage of carbon has to be put back. This latter operation is carried out by adding a precise quantity of manganiferous pig-iron (spiegel-eisen) or ferromanganese, the manganese serving to remove the oxygen, which has combined with the iron during the blow.

The controversy which surrounded its development concerned two aspects of the process: The use of the cold air blast to raise the temperature of the molten metal, and the application of manganese to overcome the problem of control of the carbon and oxygen content.

Bessemer, who began his experiments in the making of iron and steel in 1854, secured his first patent in Great Britain in January 1855, and was persuaded to present information about his discovery to a meeting of the British Association for the Advancement of Science held at Cheltenham, Gloucestershire, in August 1856. His title "The Manufacture of Iron without Fuel" was given wide publicity in Great Britain and in the United States. Among those who wrote to the papers to contest Bessemer's theories were several claimants to priority of invention.

Two men claimed that they had anticipated Bessemer in the invention of a method of treating molten metal with air-blasts for the purpose of "purifying" or decarbonizing iron. Both were Americans. Joseph Gilbert Martien, of Newark, New Jersey, who at the time of Bessemer's address was working at the plant of the Ebbw Vale Iron Works, in South Wales, secured a provisional patent a few days before Bessemer obtained one of his series of patents for making cast steel, a circumstance which provided ammunition for those who wished to dispute Bessemer's somewhat spectacular claims. William Kelly, an ironmaster of Eddyville, Kentucky, brought into action by an

American report of Bessemer's British Association paper, opposed the granting of a United States patent to Bessemer and substantiated, to the satisfaction of the Commissioner of Patents, his claim to priority in the "air boiling" process.

A third man, this one a Scot resident in England, intervened to claim that he had devised the means whereby Martien's and Bessemer's ideas could be made practical. He was Robert Mushet of Coleford, Gloucestershire, a metallurgist and self-appointed "sage" of the British iron and steel industry who also was associated with the Ebbw Vale Iron Works as a consultant. He, like his American contemporaries, has become established in the public mind as one upon whom Henry Bessemer was dependent for the origin and success of his process. Since Bessemer was the only one of the group to make money from the expansion of the steel industry consequent upon the introduction of the new technique, the suspicion has remained that he exploited the inventions of the others, if indeed he did not steal them.

In this study, based largely upon the contemporary discussion in the technical press, the relation of the four men to each other is re-examined and an attempt is made to place the controversy of 1855-1865 in focus. The necessity for a reappraisal arises from the fact that today's references to the origin of Bessemer steel² often contain chronological and other inaccuracies arising in many cases from a dependence on secondary and sometimes unreliable sources. As a result, Kelly's contribution has, perhaps, been over-emphasized, with the effect of derogating from the work of another American, Alexander Lyman Holley, who more than any man is entitled to credit for establishing Bessemer steel in America.³

Steel Before the 1850's

In spite of a rapid increase in the use of machines and the overwhelming demand for iron products for the expanding railroads, the use of steel had expanded

² See especially material distributed by the American Iron and Steel Institute in connection with its celebration of the centennial of Steel: "Steel centennial (1957), press information," prepared by Hill and Knowlton, Inc., and released by the Institute as of May 1, 1957.

³ Holley's work is outside the scope of this paper. Belatedly, his biography is now being written. It can hardly fail to substantiate the contention that during his short life (1832-1882) Holley, who negotiated the purchase of the American rights to Bessemer's process, also adapted his methods to the American scene and laid a substantial part of the foundation for the modern American steel industry.

date prior to 1855. The methods of production were still largely those of a century earlier. Slow preparation of the steel by cementation or in crucibles meant a disproportionate consumption of fuel and a resulting high cost. Production in small quantities prevented the adoption of steel in uses which required large initial masses of metal. Steel was, in fact, a luxury product.

The work of Réaumur and, especially, of Huntsman, whose development of cast steel after 1740 secured an international reputation for Sheffield, had established the cementation and crucible processes as the primary source of cast steel, for nearly 100 years. Josiah Marshall Heath's patents of 1839, were the first developments in the direction of cheaper steel, his process leading to a reduction of from 30 to 40 percent in the price of good steel in the Sheffield market.¹ Heath's secret was the addition to the charge of from 1 to 3 percent of carburet of manganese² as a deoxidizer. Heath's failure to word his patent so as to cover also his method of producing carburet of manganese led to the effective breakdown of that patent and to the general adoption of his process without payment of license or royalty. In spite of this reduction in the cost of its production, steel remained, until after the midpoint of the century, an insignificant item in the output of the iron and steel industry, being used principally in the manufacture of cutlery and edge tools.

The stimulus towards new methods of making steel and, indeed, of making new steels came curiously enough from outside the established industry, from a man who was not an ironmaster—Henry Bessemer. The way in which Bessemer challenged the trade was itself unusual. There are few cases in which a stranger to an industry has taken the risk of giving a description of a new process in a public forum like a meeting of the British Association for the Advancement of Science. He challenged the trade, not only to attack his theories but to produce evidence from their own plants that they could provide an alternative means of satisfying an emergent demand. Whether or not Bessemer is entitled to claim priority of invention, one can but agree with the ironmaster who said:³ "Mr. Bessemer has raised such a spirit of enquiry throughout . . . the

land as must lead to an improved system of manufacture."

Bessemer and his Competitors

Henry Bessemer (1813-1898), an Englishman of French extraction, was the son of a mechanical engineer with a special interest in metallurgy. His environment and his unusual ability to synthesize his observation and experience enabled Bessemer to begin a career of invention by registering his first patent at the age of 25. His active experimenting continued until his death, although the public record of his results ended with a patent issued on the day before his seventieth birthday. A total of 117 British patents⁴ bear his name, not all of them, by any means, successful in the sense of producing a substantial income. Curiously, Bessemer's financial stability was assured by the success of an invention he did not patent. This was a process of making bronze powder and gold paint, until the 1830's a secret held in Germany. Bessemer's substitute for an expensive imported product, in the then state of the patent laws, would have failed to give him an adequate reward if he had been unable to keep his process secret. To assure this reward, he had to design, assemble, and organize a plant capable of operation with a minimum of hired labor and with close security control. The fact that he kept the method secret for 40 years, suggests that his machinery⁵ (Bessemer describes it as virtually automatic in operation) represented an appreciation of coordinated design greatly in advance of his time. His experience must have directly contributed to his conception of his steel process not as a metallurgical trick but as an industrial process; for when the time came, Bessemer patented his discovery as a process rather than as a formula.

In the light of subsequent developments, it is necessary to consider Bessemer's attitude toward the patent privilege. He describes his secret gold paint as an example of "what the public has had to pay for not being able to give . . . security to the inventor" in a situation where the production of the material "could not be identified as having been made by any particular form of mechanism."⁶ The inability to obtain a patent over the method of production meant that the disclosure of his formula, necessary for patent specification, would openly invite competitors, in-

¹ Andrew Ure, *Dictionary of art, manufactures and mines*, New York, 1840, p. 735.

² See acknowledgment of British patent 8021 of 1839 quoted in James S. Jeans, *St. I.*, London, 1880, p. 28 ff. It is not clear that Heath was aware of the precise chemical effect of the use of manganese in this way.

³ *Mech. Jour.*, 1857, vol. 27, p. 465.

⁴ See *Henry Bessemer, F. R. S., an autobiography*, London, 1905, p. 332.

⁵ *Ibid.*, p. 59 ff.

⁶ *Ibid.*, p. 82.

cluding the Germans, to evolve their own techniques. Bessemer concludes:¹⁰

Had the invention been patented, it would have become public property in fourteen years from the date of the patent, after which period the public would have been able to buy bronze powder at its present *loc. cit.* 1860) market price, viz from two shillings and three pence to two shillings and nine pence per pound. But this important secret was kept for about thirty-five years and the public had to pay excessively high prices for twenty-one years longer than they would have done had the invention become public property in fourteen years, as it would have been if patented. Even this does not represent all the disadvantages resulting from secret manufacture. While every detail of production was a profound secret, there were no improvements made by the outside public in any one of the machines employed during the whole thirty-five years; whereas during the fourteen years, if the invention had been patented, there would, in all probability have been many improved machines invented and many novel features applied to totally different manufactures.

While these words, to some extent, were the rationalizations of an old man, Bessemer's career showed that his philosophy had a practical foundation; and, if this was indeed his belief, the episode explains in large measure Bessemer's later insistence on the legal niceties of the patent procedure. The effect of this will be seen.

Bessemer's intervention in the field of iron and steel was preceded by a period of experiments in the manufacture of glass. Here Bessemer claims to have made glass for the first time in the open hearth of a reverberatory furnace.¹¹ His work in glass manufacture at least gave him considerable experience in the problems of fusion under high temperatures and provided some support for his later claim that in applying the reverberatory furnace to the manufacture of malleable iron as described in his first patent of January 1855, he had in some manner anticipated the work of C. W. Siemens and Emil Martin.¹²

¹⁰ *Ibid.*, p. 83.

¹¹ *Ibid.*, p. 108 ff.

¹² *Ibid.*, p. 141. Bessemer's assertion that he had approached "within measurable distance" of anticipating the Siemens-Martin process, made in a paper presented at a meeting of the American Society of Mechanical Engineers (*Transactions of the American Society of Mechanical Engineers*, 1897, vol. 28, p. 459), evoked strong criticism of Bessemer's lack of generosity (*ibid.*, p. 482). One commentator, friendly to Bessemer, put it that "Bessemer's relation to the open-hearth process was very much like Kelly's to the Bessemer process. . . . Although he was measurably near to the open-hearth process, he did not follow it up and make it a commercial success. . . ." (*ibid.*, p. 491).

The general interest in problems of ordnance and armor, stimulated by the Crimean War (1854-1856), was shared by Bessemer, whose ingenuity soon produced a design for a projectile which could provide its own rotation when fired from a smooth-bore gun.¹³ Bessemer's failure to interest the British War Office in the idea led him to submit his design to the Emperor Napoleon III. Trials made with the encouragement of the Emperor showed the inadequacy of the cast-iron guns of the period to deal with the heavier shot; and Bessemer was presented with a new problem which, with "the open mind which derived from a limited knowledge of the metallurgy of war," he attacked with impetuosity. Within three weeks of his experiments in France, he had applied for a patent for "Improvements in the Manufacture of Iron and Steel."¹⁴ This covered the fusion of steel with pig or cast iron and, though this must be regarded as only the first practical step toward the Bessemer process,¹⁵ it was his experiments with the furnace which provided Bessemer with the idea for his later developments.

These were described in his patent dated October 17, 1855 (British patent 2321). This patent is significant to the present study because his application for an American patent, based on similar specifications, led to the interference of William Kelly and to the subsequent denial of the American patent.¹⁶ In British patent 2321 Bessemer proposed to convert his steel in crucibles, arranged in a suitable furnace and each having a vertical tuyère, through which air under pressure was forced through the molten metal. As Dredge¹⁷ points out, Bessemer's association of the air blast with the increase in the temperature of the metal "showed his appreciation of the end in view, and the general way of attaining it, though his mechanical details were still crude and imperfect."

Experiments were continued and several more British patents were applied for before Bessemer made his appearance before the British Association

¹³ British patent 2489, November 23, 1854.

¹⁴ Bessemer, *op. cit.* footnote 7, p. 137. He received British patent 66, dated January 10, 1855.

¹⁵ See James W. Dredge, "Henry Bessemer, 1813-1898," *Transactions of the American Society of Mechanical Engineers*, 1898, vol. 19, p. 911.

¹⁶ See U. S. Patent Office, Decision of Commissioner of Patents, dated April 13, 1857, in Kelly vs. Bessemer Interference. This is further discussed below (p. 42).

¹⁷ Dredge, *op. cit.* footnote 15, p. 912.

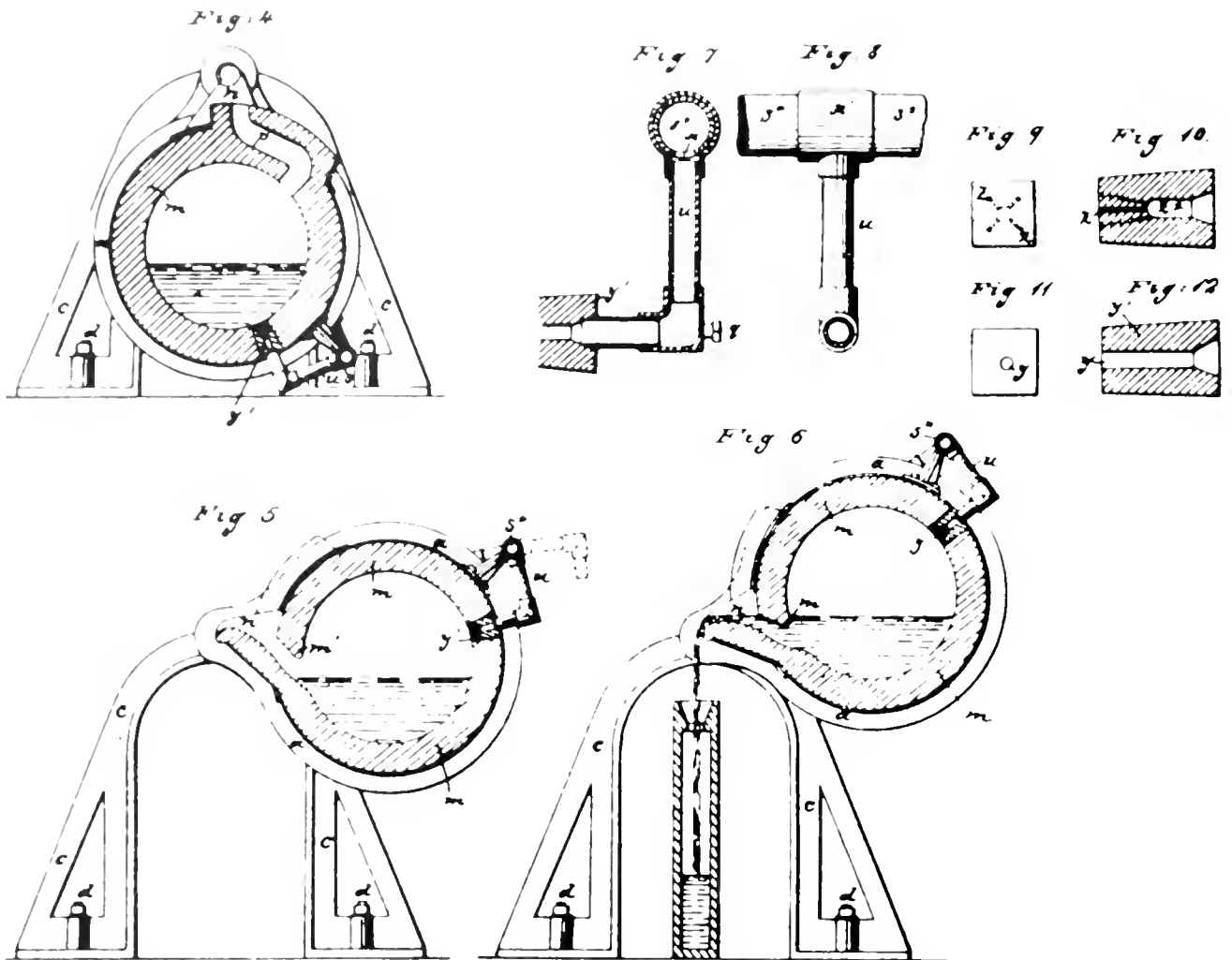


Figure 1. BESSEMER'S DESIGN FOR A CONVERTER, AS SHOWN IN U. S. PATENT 16082. This patent, dated November 11, 1856, corresponds with British patent 356, dated February 12, 1856. The more familiar design of converter appeared first in British patent 578, March 1, 1860. The contrast with Kelly's schematic drawing in Fig. 2 (p. 42) is noticeable.

on August 13, 1856.¹⁸ Bessemer described his first converter and its operation in some detail. Although he was soon to realize that he "too readily allowed myself to bring my inventions under public notice,"¹⁹ Bessemer had now thrown out a challenge which eventually had to be taken up, regardless of the strength of the vested interests involved. The prov-

¹⁸ Bessemer's paper was reported in *The Times*, London, August 14, 1856. By the time the Transactions of the British Association were prepared for publication, the controversy aroused by Bessemer's claim to manufacture "malleable iron and steel without fuel" had broken out and it was decided not to report the paper. Dredge, *op. cit.*, footnote 15, p. 915, describes this decision as "satisfactory."

¹⁹ Bessemer, *Transactions*, p. 163.

ocation came from his claims that the product of the first stage of the conversion was the equivalent of charcoal iron, the processes following the smelting being conducted without contact with, or the use of, any mineral fuel; and that further blowing could be used to produce any quality of metal, that is, a steel with any desired percentage of carbon. Yet, the principal irritant to the complacency of the ironmaster must have been Bessemer's attack on an industry which had gone on increasing the size of its smelting furnaces, thus improving the uniformity of its pig-iron, without modifying the puddling process, which at best could handle no more than 400 to 500 pounds of iron at a time, divided into the "homeo-

pathic doses" of 70 or 80 pounds capable of being handled by human labor.²⁰ Bessemer's claim to "do" 800 pounds of metal in 30 minutes against the puddling furnace's output of 500 pounds in two hours was calculated to arouse the opposition of those who feared the loss of capital invested in puddling furnaces and of those who suspected that their jobs might be in jeopardy. The ensuing criticism of Bessemer has to be interpreted, therefore, with this in mind; not by any means was it entirely based on objective consideration of the method or the product.²¹

Within a month of his address, Bessemer had sold licenses to several ironmasters (outside Sheffield) and so provided himself with capital with which to continue his development work; but he refused to sell his patents outright to the Ebbw Vale Iron Works and by this action, as will be seen, he created an enemy for himself.

The three years between 1856 and 1859, when Bessemer opened his own steel works in Sheffield, were occupied in tracing the causes of his initial difficulties. There was continued controversy in the technical press. Bessemer (unless he used a *nom-de-plume*) took no part in it and remained silent until he made another public appearance before the Institution of Civil Engineers in London (May 1859). By this time Bessemer's process was accepted as a practical one, and the claims of Robert Mushet to share in his achievement was becoming clamorous.

ROBERT MUSHET

Robert (Forester) Mushet (1811-1891), born in the Forest of Dean, Gloucestershire, of a Scots father (David, 1772-1847) himself a noted contributor to the metallurgy of iron and steel, is, like the American William Kelly, considered by many to have been a victim of Bessemer's astuteness—or villainy. Because of Robert Mushet's preference for the quiet of Coleford, many important facts about his career are lacking; but even if his physical life was that of a recluse, his frequent and verbose contributions to the correspondence columns of the technical press made him well-known to the iron trade. It is from these letters that he must be judged.

In view of his propensity to intervene pontifically in

every discussion concerning the manufacture of iron and steel, it is somewhat surprising that he refrained from comment on Bessemer's British Association address of August 1856 for more than fourteen months. The debate was opened over the signature of his brother David who shared the family facility with the pen.²² Recognizing Bessemer's invention as a "congruous appendage to [the] now highly developed powers of the blast furnace" which he describes as "too convenient, too powerful and too capable of further development to be superseded by any retrograde process," David Mushet greeted Bessemer's discovery as "one of the greatest operations ever devised in metallurgy."²³ A month later, however, David Mushet had so modified his opinion of Bessemer as to come to the conclusion that the latter "must indeed be classed with the most unfortunate inventors." He gave as his reason for this turnabout his discovery that Joseph Martien had demonstrated his process of "purifying" metal successfully and had indeed been granted a provisional patent a month before Bessemer. The sharp practice of Martien's patent lawyer, Mushet claimed, had deprived him of an opportunity of proving priority of invention against Bessemer. Mushet was convinced that Martien's was the first in the field.²⁴

Robert Mushet's campaign on behalf of his own claims to have made the Bessemer process effective was introduced in October 1857, two years after the beginning of Bessemer's experiment and after one year of silence on Bessemer's part. Writing as "Sideros"²⁵ he gave credit to Martien for "the great

²² See *Mining Journal*, 1857, vol. 27, pp. 839 and 855. David Mushet withdrew from the discussion after 1858 and his relapse into obscurity is only broken by an appeal for funds for the family of Henry Cort. A biographer of the Mushets is of the opinion that Robert Mushet wrote these letters and obtained David's signature to them (Fred M. Osborn, *The Mushets and the Mushets*, London, 1952, p. 34, footnote). The similarity in the style of the two brothers is extraordinary enough to support this idea. If this is so, Robert Mushet who disagreed with himself as "Sideros" was also in controversy with himself writing as "David."

²³ *Mining Journal*, 1856, vol. 26, p. 507.

²⁴ *Ibid.*, pp. 631 and 637. The case of Martien will be discussed below (p. 30). David Mushet had overlooked Bessemer's patent of January 19, 1855.

²⁵ *Mining Journal*, 1857, vol. 27, p. 723. Robert Mushet was a constant correspondent of the *Mining Journal* from 1848. The adoption of a pseudonym, peculiar apparently to 1855-1858 (see *Dictionary of the History of Ideas*, vol. 3, p. 429), enabled him to carry on two debates at a time, and a less to himself, as he writes.

²⁰ *The Times*, London, August 14, 1856.

²¹ David Mushet recognized that Bessemer's great feature was this effort to "raise the after processes . . . to a level commensurate with the preceding case." *Mining Journal*, 1856, p. 599.

... by blowing pig-iron can, whilst in the fluid state, be purified . . . by forcing currents of air under it . . . though Martien had failed to observe the rise of temperature by the "detonation of the iron itself"; and for discovering that

when the carbon has been all, or nearly all, dissipated, the temperature increases to an almost inconceivable extent, so that the mass, when containing only as much carbon as is requisite to constitute with it cast steel . . . still retains a perfect degree of fluidity.

This, says "Sideros," was no new observation; "it had been before the metallurgical world, both practical and scientific, for centuries," but Bessemer was the first to show that this generation of heat could be attained by blowing cold air through the melted iron. Mushet goes on to show, however, that the steel thus produced by Bessemer was not commercially valuable because the sulphur and phosphorus remained, and the dispersion of oxide of iron through the mass "imported to it the inveterate hot-short quality which no subsequent operation could expel." "Sideros" concludes that Bessemer's discovery was "at least for a time" now shelved and arrested in its progress; and it had been left "to an individual of the name of Mushet" to show that if "fluid metallic manganese" were combined with the fluid Bessemer iron, the portion of manganese thus alloyed would unite with the oxygen of the oxide and pass off as slag, removing the hot-short quality of the iron. Robert Mushet had demonstrated his product to "Sideros" and had patented his discovery, though "not one print, literary or scientific, had condescended to notice it."

"Sideros" viewed Mushet's discovery as a "spark amongst dry faggots that will one day light up a blaze which will astonish the world when the unfortunate inventor can no longer reap the fruits of his life-long toil and unflinching perseverance." In an ensuing letter he²⁶ summed up the situation as he saw it:

Nothing that Mr. Mushet can hereafter invent can entitle him to the merit of Mr. Bessemer's great discovery . . . and . . . nothing that Mr. Bessemer may hereafter patent can deprive Mr. Robert Mushet of having been the first to remove the obstacles to the success of Mr. Bessemer's process.

Bessemer still did not intervene in the newspaper

²⁶ *Ibid.*, p. 823. Mushet's distinction between an inventor and a patentee is indicative of the disdain of a son of David Mushet for an amateur: see also p. 886.

discussion; nor had he had any serious supporters, at least in the early stage.²⁷

Publication in the *Mining Journal* of a list of Mushet's patents,²⁸ evidently in response to Sideros' complaint, now presented Bessemer with notice of Robert Mushet's activity, even if he had not already observed his claims as they were presented to the Patent Office. Mushet, said the *Mining Journal* –

appears to intend to carry on his researches from the point where Mr. J. G. Martien left off and is proceeding on the Bessemer plan of patenting each idea as it occurs to his imaginative brain. He proposes to make both iron and steel but does not appear to have quite decided as to the course of action . . . to accomplish his object, and therefore claims various processes, some of which are never likely to realize the inventor's expectations, although decidedly novel, whilst others are but slight modification of inventions which have already been tried and failed.

The contemporary attitude is reflected in another comment by the *Mining Journal*:²⁹

Although the application of chemical knowledge to the manufacture of malleable iron cannot fail to produce beneficial results, the quality of the metal depends more upon the mechanical than the chemical processes . . . Without wishing in any way to discourage the iron chemists, we have no hesitation in giving this as our opinion which we shall maintain until the contrary be actually proved. With regard to steel, there may be a large field for chemical research . . . however, we believe that unless the iron be of a nature adapted for the manufacture of steel by ordinary processes, the purely chemical inventions will only give a metal of a very uniform quality.

Another correspondent, William Green, was of the opinion that Mushet's "new compounds and alloys," promised well as an auxiliary to the Bessemer process but that "the evil which it was intended to remove was more visionary than real," Bessemer's chief difficulty was the phosphorus, not the oxide of iron "as Mr. Mushet assumes." This, Bessemer no doubt would deal with in due course, but meanwhile he did well "to concentrate his energies upon the steel opera-

²⁷ One William Green had commented extensively on David Mushet's early praise of the Bessemer process and on his sudden reversal in favor of Martien soon after Bessemer's British Association address (*Mechanics' Magazine*, 1856, vol. 65, p. 373 ff.). Green wrote from Caledonian Road, and the proximity to Baxter House, Bessemer's London headquarters, suggests the possibility that Green was writing for Bessemer.

²⁸ *Mining Journal*, 1857, vol. 27, p. 764.

²⁹ *Ibid.*, p. 764.

tions," after which he would have time to tackle "the difficulties which have so far retarded the iron operations."³⁰

Mushet³¹ claims to have taken out his patent of September 22, 1856, covering the famous "triple compound," after he

had fully ascertained, upon the ordinary scale of manufacture that air-purified cast-iron, when treated as set forth in my specifications, would afford tough malleable iron . . . I found, however, that the remelting of the coke pig-iron, in contact with coke fuel, hardened the iron too much, and it became evident that an air-furnace was more proper for my purpose . . . [the difficulties] arose, not from any defect in my process, but were owing to the small quantity of the metal operated upon and the imperfect arrangement of the purifying vessel, which ought to be so constituted that it may be turned upon an axis, the blast taken off, the alloy added and the steel poured out through a spout . . . *Such a purifying vessel Mr. Bessemer has delineated in one of his patents.*

Mushet also claimed to have designed his own "purifying and mixing" furnace, of 20-ton capacity, which he had submitted to the Ebbw Vale Iron Works "many months ago," without comment from them. There is an intriguing reference to the painful subject of two patents not proceeded with, and not discussed "in the avaricious hope that the parties connected with the patents will make me honorable amends . . . these patents were suppressed without my knowledge or consent." Lest his qualifications should be questioned, Mushet concludes:

I do not profess to be an iron chemist, but I have undoubtedly made more experiments upon the subject of iron and steel than any man now living and I am thereby enabled to say that all I know is but little in comparison with what has yet to be discovered.

So began Mushet's claim to have solved Bessemer's problem, a claim which was to fill the correspondence columns of the engineering journals for the next ten years. Interpretation of this correspondence is made difficult by our ignorance of the facts concerning the control of Mushet's patents. These have to be pieced together from his scattered references to the subject.

His experiments were conducted, at least nearly up to the close of the year 1856, with the cooperation of Thomas Brown of the Ebbw Vale Iron Works.³² The price of this assistance was apparently half interest in Mushet's patents, though for reasons which Mushet does not explain the deed prepared to effect

the transfer was never executed. Mushet continued, however, to regard the patents as "wholly my own, though at the same time, I am bound in honor to take no unfair advantage of the non-execution of that deed." A possible explanation of this situation may be found in Ebbw Vale's activities in connection with Martien and Bessemer, as well as with an Austrian inventor, Uchatius.

Ebbw Vale and the Bessemer Process

After his British Association address in August 1856, Bessemer had received applications from several ironmasters for licenses, which were issued in return for a down payment and a nominal royalty of 25 pence per ton. Among those who started negotiations was Mr. Thomas Brown of Ebbw Vale Iron Works, one of the largest of the South Wales plants. He proposed, however, instead of a license, an outright purchase of Bessemer's patents for £50,000. Bessemer refused to sell, and according to his³³ account

intense disappointment and anger quite got the better of [Brown] and for the moment he could not realize the fact of my refusal . . . [He then] left me very abruptly, saying in an irritated tone . . . "I'll make you see the matter differently yet" and slammed the door after him.

David Mushet's advocacy of Martien's claim to priority over Bessemer has already been noticed (p. 33). From him we learn³⁴ that Martien's experiments leading to his patent of September 15, 1855, had been carried out at the Ebbw Vale Works in South Wales, where he engaged in "perfecting the Renton process."³⁵ Martien's own process consisted in passing air through metal as it was run in a trough from the furnace and before it passed into the puddling furnace.

It is known that Martien's patent was in the hands of the Ebbw Vale Iron Works by March 1857.³⁶ This fact must be added to our knowledge that Mushet's patent of September 22, 1856 was drawn up with a specific reference to the application of his "triple

³⁰ *Ibid.*, p. 823.

³¹ Bessemer, *op. cit.* footnote 7, p. 10.

Minutes 7, *op. cit.*, 1856, vol. 26, p. 681.

James Renton's process (U. S. patent 8013, December 23, 1851) had been developed at Newark, New Jersey, in 1851. It was a modification of the puddling furnace, in which the ore and carbon were heated in tubs, utilizing the waste heat of the reverberatory furnace (see the *Mem. of the M. S. Soc.*, vol. 62, p. 246, 1855). Renton died at Newark in September 1856 (*Mem. of the M. S. Soc.*, 1856, vol. 65, p. 422).

³² *Minutes* 7, *op. cit.*, 1857, vol. 27, p. 193.

compound to "iron . . . purified by the action of air, in the manner invented by Joseph Gilbert Martien,"³⁷ and that this and his other manganese patents were under the effective control of Ebbw Vale. It seems a reasonable deduction from these circumstances that Brown's offer to buy out Bessemer and his subsequent threat were the consequences of a determination by Ebbw Vale to attack Bessemer by means of patent infringement suits.

Some aspects of the Ebbw Vale situation are not yet explained. Martien came to South Wales from Newark, New Jersey, where he had been manager of Renton's Patent Semi-Bituminous Coal Furnace, owned by James Quimby, and where he had something to do with the installation of Renton's first furnace in 1854. The first furnace was unsuccessful.³⁸ Martien next appears in Britain, at the Ebbw Vale Iron Works. No information is available as to whether Martien's own furnace was actually installed at Ebbw Vale, although as noted above, David Mushet claims to have been invited to see it there.

Martien secured an American patent for his process in 1857 and to file his application appears to have gone to the United States, where he remained at least until October 1858.³⁹ He seems to have taken the opportunity to apply for another patent for a furnace similar to that of James Renton. This led to interference proceedings in which Martien showed that he had worked on this furnace at Bridgend, Glamorganshire (one of the Ebbw Vale plants), improving Renton's design by increasing the number of "de-oxidizing tubes." This variation in Renton's design was held not patentable, and in any case Renton's firm was able to show that they had successfully installed the furnace at Newark in 1852-1853, while Martien could not satisfy the Commissioner that his installation had been made before September 1854. Priority was therefore awarded to Quimby, Brown, Renton, and Creswell.⁴¹

³⁷ British patent 2219, September 22, 1856.

³⁸ Joseph P. Lesley, *The iron manufacturer's guide*, New York, 1859, p. 34. Martien's name is spelled Marteen. A description of the furnace is given in *Scientific American* of February 11, 1854, (vol. 9, p. 169). In the patent interference proceedings referred to below, it was stated that the furnace was in successful operation in 1854.

³⁹ U. S. patent 16690, February 22, 1857. A correspondent of the *Mining Journal* (1858, vol. 28, p. 713) states that Martien had not returned to England by October 1858.

⁴⁰ U. S. Patent Office, Decision of Commissioner of Patents, dated May 26, 1859 in the matter of interference between the application of James M. Quimby and others . . . and of Joseph Martien.

Since Renton had not patented his furnace in Great Britain, Martien's use of his earlier knowledge of Renton's work and of his experience at Bridgend in an attempt to upset Renton's priority is a curious and at present unexplainable episode. Perhaps the early records of the Ebbw Vale Iron Works, if they exist, will show whether this episode was in some way linked to the firm's optimistic combination of the British patents of Martien and Mushet.

That Ebbw Vale exerted every effort to find an alternative to Bessemer's process is suggested, also, by their purchase in 1856 of the British rights to the Uchatius process, invented by an Austrian Army officer. The provisional patent specifications, dated October 1, 1855, showed that Uchatius proposed to make cast steel directly from pig-iron by melting granulated pig-iron in a crucible with pulverized "sparry iron" (siderite) and fine clay or with gray oxide of manganese, which would determine the amount of carbon combining with the iron. This process, which was to prove commercially successful in Great Britain and in Sweden but was not used in America,⁴² appeared to Ebbw Vale to be something from which, "we can have steel produced at the price proposed by Mr. Bessemer, notwithstanding the failure of his process to fulfil the promise."⁴³

So far as is known only one direct attempt was made, presumably instigated by Ebbw Vale, to enforce their patents against Bessemer, who records⁴⁴ a visit by Mushet's agent some two or three months before a renewal fee on Mushet's basic manganese patents became payable in 1859. Bessemer "entirely repudiated" Mushet's patents and offered to perform his operations in the presence of Mushet's lawyers and witnesses at the Sheffield Works so that a prosecution for infringement "would be a very simple matter." That, he says, was the last heard from the agent or from Mushet on the subject.⁴⁵ The renewal fee was not paid and the patents were therefore abandoned by Ebbw Vale and their associates, a

⁴² J. S. Jeans, *op. cit.* (footnote 5), p. 108. The process is not mentioned by James M. Swank, *History of the manufacture of iron in all ages*, Philadelphia, American Iron and Steel Association, 1892.

⁴³ *Mining Journal*, 1856, vol. 26, p. 707.

⁴⁴ Bessemer, *op. cit.* (footnote 7), p. 290.

⁴⁵ The American Iron and Steel Institute's "Steel centennial (1957) press information" (see footnote 2), includes a pamphlet, "Kelly lighted the fireworks . . ." by Vaughn Shelton (New York, 1956), which asserts (p. 12) that Bessemer paid the renewal fee and became the owner of Mushet's "vital" patent.

fact which did not come to Mushet's knowledge until 1861, when he himself declared that the patent "was never in my hands at all [so] that I could not enforce it."⁴⁶

Further support for the thesis that Ebbw Vale's policy was in part dictated by a desire to make Bessemer "see the matter differently" is to be found in the climatic episode. Work on Martien's patents had not been abandoned and in 1861 certain patents were taken out by George Parry, Ebbw Vale's furnace manager. These, represented as improvements of Martien's designs, were regarded by Bessemer as clear infringements of his own patents.⁴⁷ When it came to Bessemer's knowledge that Ebbw Vale was proposing to "go to the public" for additional capital with which to finance, in part, a large scale working of Parry's process, he threatened the financial promoter with injunctions and succeeded in opening negotiations for a settlement. All the patents "which had been for years suspended" over Bessemer were turned over to him for £30,000. Ebbw Vale, thereupon, issued their prospectus⁴⁸ with the significant statement that the directors "have agreed for a license for the manufacture of steel by the Bessemer process which, from the peculiar resources they possess, they will be enabled to produce in very large quantities. . . ." So Bessemer became the owner of the Martien and Parry patents. Mushet's basic patents no longer existed.

Mushet and Bessemer

That Mushet was "used" by Ebbw Vale against Bessemer is, perhaps, only an assumption; but that he was badly treated by Ebbw Vale is subject to no doubt. Mushet's business capacity was small but it is difficult to believe that he could have been so foolish as to assign an interest in his patents to Ebbw Vale without in some way insuring his right of consultation about their disposition. He claims that even in the drafting of his specifications he was obliged to follow the demands of Ebbw Vale, which firm, believing, "on the advice of Mr. Hindmarsh, the most eminent patent counsel of the day,"⁴⁹ that Martien's patent outranked Bessemer's, insisted that Mushet link his

process to Martien's. Thus, as late as 1861, Mushet believed to be in effective operation.⁵⁰ His later repudiation of the process as an absurd and impracticable patent process "possessing neither value nor utility"⁵¹ may more truly represent his opinion, especially as, when he wrote his 1861 comment, he still did not know of the disappearance of his patents.

Mushet's boast⁵² that he had never been into an ironworks other than his own in Coleford is a clue to the interpretation of his behavior in general and also of his frequent presumptuous claims. When, for instance, the development of the Uchatius process was publicized, he gave his opinion⁵³ that the process was a useless one and had been patented before Uchatius "understood its nature"; yet later⁵⁴ he could claim that the process was "in fact, my own invention and I had made and sold the steel thus produced for some years previously to the date of Captain Uchatius' patent." Moreover, he claims to have instructed Uchatius' agents in its operation! He may, at this later date, have recalled his challenge (the first of many such) in which he offered Uchatius' agent in England to pay a monetary penalty if he could not show a superior method of producing "sound serviceable cast steel from British coke pig-iron, *on the stomach plan* and without any mixture of clay, oxide of manganese or any of these pot destroying ingredients."⁵⁵

It was David Mushet (or Robert, using his brother's name)⁵⁶ who accused Bessemer, or rather his patent agent, Carpmael, of sharp practice in connection with Martien's specification, an allegation later supported by Martien's first patent agent, Avery.⁵⁷ The story was that for the drafting of his final specification, Martien, presumably with the advice of the Ebbw Vale Iron Works, consulted the same Carpmael, as "the leading man" in the field. The latter advised that the provisional specification restricted Martien to the application of his method to iron flowing in a channel or gutter from the blast furnace, and so prevented him from applying his aeration principle in any kind of receptacle. In effect, Carpmael was

⁴⁶ *Ibid.*, p. 78.

⁴⁷ Mushet, *op. cit.* (footnote 46), p. 9.

Ibid., p. 25.

Mining Journal, 1857, vol. 27, p. 755.

⁴⁸ Mushet, *op. cit.* (footnote 46), p. 28. The Uchatius process became the "You-cheat-us" process to Mushet (*Mining Journal*, 1858, vol. 28, p. 34).

Mining Journal, 1857, vol. 27, p. 755 (italics supplied).

⁴⁹ See footnote 22.

Mining Journal, 1856, vol. 26, pp. 583, 631.

⁴⁴ Robert Mushet, *The Bessemer-Mushet process*, Cheltenham, 1883, p. 24; *The Engineer*, 1861, vol. 12, pp. 177 and 189.

⁴⁵ *The Engineer*, 1862, vol. 13, p. 3. Bessemer, *op. cit.* (footnote 7), p. 296.

⁴⁶ *Mining Journal*, 1864, vol. 34, p. 478.

⁴⁷ *The Engineer*, 1861, vol. 12, p. 189.

acting unprofessionally by giving Bessemer the prior claim to the use of a receptacle. According to Mushet, Martien had in fact "actually and publicly proved" his process in a receptacle and not in a gutter, so that his claim to priority could be maintained on the basis of the provisional specification.

This, like other Mushet allegations, was ignored by Bessemer, and probably with good reason. At any rate, Martien's American patent is in terms similar to those of the British specification; he or his advisers seem to have attached no significance to the distinction between a gutter and a receptacle.

Mushet's claim to have afforded Bessemer the means of making his own process useful is still subject to debate. Unfortunately, documentation of the case is almost wholly one-sided, since his biggest publicizer was Mushet himself. An occasional editorial in the technical press and a few replies to Mushet's "incubations" are all the material which exists, apart from Bessemer's own story.

Mushet and at least five other men patented the use of manganese in steel making in 1856; his own provisional specification was filed within a month of the publication of Bessemer's British Association address in August 1856. So it is strange that Robert Mushet did not until more than a year later join in the controversy which followed that address.⁵⁸ In one of his early letters he claims to have made of "his" steel a bridge rail of 750 pounds weight; although his brother insists that he saw the same rail in the Ebbw Vale offices in London in the spring of 1857, when it was presented as a specimen of Uchatius steel!⁵⁹ Robert Mushet's indignant "advertisement" of January 5, 1858,⁶⁰ reiterating his parentage of this sample, also claimed a double-headed steel rail "made by me under another of my patent processes," and sent to Derby to be laid down there to be "subjected to intense vertical triturations." Mushet's description of the preparation of this ingot⁶¹ shows that it was derived from "Bessemer scrap" made by Ebbw Vale in the first unsuccessful attempts of that firm to simulate the Bessemer process. This scrap Mushet had remelted in pots with spiegel in the proportions of 44 pounds of scrap to 3 of melted spiegel. It was

his claim that the rail was rolled direct from the ingot, something Bessemer himself could not do at that time.

This was the beginning of a series of claims by Mushet as to his essential contributions to Bessemer's invention. The silence of the latter during this period is impressive, for according to Bessemer's own account⁶² his British Association address was premature, and although the sale of licenses actually provided him with working funds, the impatience of those experimenting with the process and the flood of competing "inventions" all embarrassed him at the most critical stage of this development of the process: "It was, however, no use for me to argue the matter in the press. All that I could say would be mere talk and I felt that action was necessary, and not words."⁶³

Action took the form of continued experiments and, by the end of 1857, a decision to build his own plant at Sheffield.⁶⁴ An important collateral development resulted from the visit to London in May 1857 of G. F. Goransson of Gelle, Sweden. Using Bessemer equipment, Goransson began trials of the process in November 1857 and by October 1858 was able to report: "Our firm has now entirely given up the manufacture of bar iron, and our blast furnaces and tilt mills are now wholly employed in making steel by the Bessemer process, which may, therefore, be now considered an accomplished commercial fact."⁶⁵

Goransson was later to claim considerable improvements on the method of introducing the blast, and, in consequence, the first effective demonstration of the Bessemer method⁶⁶—this at a time when Bessemer was still remelting the product of his converter in crucibles, after granulating the steel in water. If Mushet is to be believed, this success of Goransson's was wholly due to his ore being "totally free from phosphorous and sulphur."⁶⁷ However, Bessemer's own progress was substantial, for his Sheffield works were reported as being in active operation in April 1859, and a price for his engineers' tool and spindle steel was

⁵⁸ Bessemer, *op. cit.* (footnote 7), pp. 161 ff. and 256 ff.

⁵⁹ *Ibid.*, p. 171.

⁶⁰ This enterprise, started in conjunction with Galloway's of Manchester, one of the firms licensed by Bessemer to make his equipment, was under way by April 1858 (see *Mining Journal*, 1858, vol. 28, p. 259).

⁶¹ *Mining Journal*, 1858, vol. 28, p. 696. Mushet commented (p. 713) that he had done the same thing "eighteen months ago."

⁶² Swank, *op. cit.* (footnote 42), p. 405.

⁶³ *The Engineer*, 1859, vol. 7, p. 350.

October 17, 1857, writing as "Sideros" (*Mining Journal*, 1857, vol. 27, p. 723).

Mining Journal, 1857, vol. 27, p. 871, and 1858, vol. 28, p. 52.

Ibid. (1858), p. 54.

Mushet, *op. cit.* (footnote 46), p. 12. The phrase quoted is typical of Mushet's style.

included in the *Mining Journal* "Mining Market" weekly quotations for the first time⁶⁸ on June 4, 1859.

In May 1859 Bessemer gave a paper, his first public pronouncement since August 1856, before the Institution of Civil Engineers.⁶⁹ The early process, he admitted, had led to failure because the process had not reduced the quantity of sulphur and phosphorous, but his account is vague as to the manner in which he dealt with this problem:

Steam and pure hydrogen gas were tried, with more or less success in the removal of sulphur, and various fluxes, composed chiefly of silicates of the oxide of iron and manganese were brought in contact with the fluid metal, during the process and the quantity of phosphorous was thereby reduced.

But the clear implication is that the commercial operation at Sheffield was based on the use of the best Swedish pig iron and the hematite pig from Workington. The use of manganese as standard practice at this time is not referred to,⁷⁰ but the rotary converter and the use of ganister linings are mentioned for the first time.

Mushet had, with some intuition, found opportunity to reassert his contributions to Bessemer a few days before this address, describing his process as perhaps lacking "the extraordinary merit of Mr. Bessemer," being "merely a vigorous offshoot proceeding from that great discovery; but, combined with Mr. Bessemer's process, it places within the reach of every iron manufacturer to produce cast steel at the same cost for which he can now make his best iron."⁷¹

One of Mushet's replies to the paper itself took the form of the announcement of his provisional patent for the use of his triple compound which, in the opinion of *The Mining Journal* appeared to be "but a very slight modification of several of Mr. Bessemer's inventions." Another half dozen patents appeared within two months, "so that it is apparent that Mr. Mushet's

failure to make the public appreciate his theories has not injured his inventive faculties."⁷² These patents include, besides variations on his "triple compound" theme, his important patent on the use of tungsten for cutting tools, later to be known as Mushet steel.

Mushet's formal pronouncement on Bessemer's paper, dated June 28, 1859, is perhaps his most intelligible communication on the subject. He alone "from the first consistently advocated the merits and pointed out the defects of the Bessemer process," and within a few days of the British Association address he had shown Ebbw Vale "where the defect would be found and what would remedy" it. It was not, in fact, the presence of one-tenth of a percent of sulphur or phosphorous which affected the result if the Bessemer process were combined with his process by adding a triple compound of iron, carbon, and manganese to the pig. "There never was a bar of first-rate cast steel made by the Bessemer process alone"; (and that included Goransson's product) "and there never can be, but a cheap kind of steel applicable to several purposes may be thus produced." After emphasizing the uniqueness of his attempt to make Bessemer's process successful, he asserts:⁷³

In short, I merely availed myself of a great metallurgical fact, which has been for years before the eyes of the metallurgical world, namely that the presence of metallic manganese in iron and steel conferred upon both an amount of toughness either when cold or when heated, which the presence at the same time of a notable amount of sulphur and phosphorous could not overcome.

The succeeding years were enlivened, one by one, by some controversy in which Mushet invoked the shadow of his late father as support for some pronouncement, or "edict," as some said, on the subject of making iron and steel. In 1860, on the question of suitable metal for artillery, later to be the subject of high controversy among the leading experts of the day, Mushet found a ready solution in his own gun metal. This he had developed fifteen years before. It was of a tensile strength better even than that of Krupp of Essen who was then specializing in the making of large blocks of cast steel for heavy forgings, and particularly for guns. Indeed, he was able

⁶⁸ *Mining Journal*, 1859, vol. 29, pp. 396 and 401. The price quotation was continued until April 1865.

⁶⁹ *The Engineer*, 1859, vol. 7, p. 437.

⁷⁰ Jeans, *op. cit.* (footnote 5), p. 349 refers to the hematite ores of Lancashire and Cumberland as "the ores hitherto almost exclusively used in the Bessemer process."

A definitive account of the Swedish development of the Bessemer process, leading to a well-documented claim that the first practical realization of the process was achieved in Sweden in July 1858, was recently published (Per Carlberg, "Early Production of Bessemer Steel at Lidsken," *Journal of the Iron and Steel Institute, Great Britain*, July 1958, vol. 189, p. 201).

⁷¹ *The Engineer*, 1859, vol. 7, p. 314. Bessemer's intention to present his paper had been announced in April.

⁷² See Jeans, *op. cit.* (footnote 5), p. 532.

⁷³ *The Engineer*, 1859, vol. 8, p. 13 (italics supplied). It is noted that Mushet's American patent (17389, of May 23, 1855) prefers the use of iron "as free as possible from Sulphur and Phosphorous."

publicly to challenge Krupp to produce a cast iron metal or cast steel to stand test against his.⁷⁵ A year later his attack on the distinguished French metallurgist Freny, whom he describes as an "ass" for his interest in the so-called cyanogen process of steel making, did little to enhance his reputation, whatever the scientific justification for his attack. His attitude toward the use of New Zealand (Taranaki) metaliferous sand, which he had previously favored and then condemned in such a way as to "injure a project he can no longer control,"⁷⁶ was another example of a public behavior evidently resented.

By mid-1861, on the other hand, Bessemer was beginning to meet with increasing respect from the trade. The Society of Engineers received a dispassionate account of the achievement at the Sheffield Works from E. Riley, whose firm (Dowlais) was among the earlier and disappointed licensees of the process.⁷⁷ In August 1861, five years after the ill-fated address before the British Association, the Institution of Mechanical Engineers, meeting in Sheffield, the center of the British steel trade, heard papers from Bessemer and from John Brown, a famous ironmaster. The latter described the making of Bessemer rails, the product which above all was to absorb the Bessemer plants in America after 1865. After the meeting, the engineers visited Bessemer's works; and later it was reported,⁷⁸ "at Messrs. John Brown and Company's works, the Bessemer process was repeated on a still larger scale and a heavy armor plate rolled in the presence of some 250 visitors. . . ."

These proceedings invited Robert Mushet's intervention. Still under the impression that his patent was still alive and, with Martien's, in the "able hands" of the Ebbw Vale Iron Company, he condemned Bessemer for his "lack of grace" to do him justice, and took the occasion to indict the patent system which denied him and Martien the fruits of their labors.⁷⁹

The Engineer found Mushet's position untenable on the very grounds he was pleading—that patents should not be issued to different men at different times for the same thing; and showed that Bessemer in his patents of January 4, 1856, and later, had clearly anticipated Mushet. In a subsequent article,

⁷⁵ *The Engineer*, 1860, vol. 9, pp. 366, 416, and *passim*.

⁷⁶ *The Engineer*, 1861, vol. 11, pp. 189, 202, 290, 304.

⁷⁷ *The Engineer*, 1861, vol. 12, p. 10.

⁷⁸ *Ibid.*, p. 63.

⁷⁹ *Ibid.*, pp. 8 and 11.

The Engineer disposed of Martien's and Mushet's claims with a certain finality. The Ebbw Vale Iron Works had spent £7,000 trying to carry out the Martien process and it was unlikely that they would have allowed Bessemer to infringe upon that patent if they had any grounds for a case. Bessemer was not imitating Mushet. The latter's "triple compound" required manganese pig-iron (with a content of 2 to 5 percent of manganese) at £13 per ton while Bessemer used an oxide of manganese (at a 50 percent concentration): at £7 per ton.

The alloy of manganese and other materials now used in the atmospheric process contains 50 percent of manganese, a proportion which could never be obtained from the blast furnace, owing to the highly oxidisable nature of that metal. And it is absolutely necessary, in order to apply any useful alloy of iron, carbon and manganese, in the manufacture of malleable iron and very soft steel that the manganese should be largely in excess of the carbon present.⁸⁰

Sufficient answer to Mushet was at any rate available in the fact that many hundreds of tons of excellent "Bessemer metal" made without any mixture of manganese or spiegeleisen in any form were in successful use. And, moreover, spiegeleisen was not a discovery of Robert Mushet or an exclusive product of Germany since it had been made for twenty years at least from Tow Law (Durham) ores. If Bessemer had refused Mushet a license (and this was an admitted fact), Bessemer's refusal must have been made in self-defense:

Mr. Mushet having set up a number of claims for "improvements" upon which claims, we have a right to suppose, he was preparing to take toll from Mr. Bessemer, but which claims, the latter gentleman discovered, in time, were worthless and accordingly declined any negotiations with the individual making them.⁸¹

Mushet's claims were by this time rarely supported in the periodicals. One interesting article in his favor came in 1864 from a source of special interest to the American situation. Mushet's American patent⁸² had

⁸⁰ *Ibid.*, p. 208. There is an intriguing reference in this editorial to an interference on behalf of Martien against a Bessemer application for a U. S. patent. No dates are given and the case has not been located in the record of U. S. Patent Commissioner's decision.

⁸¹ *Ibid.*, p. 254.

⁸² U. S. patent 17389, dated May 26, 1857. The patent was not renewed when application was made in 1870, on the grounds that the original patent had been made co-terminal with the British patent. The latter had been abandoned "by Mushet's own fault" so that no right existed to an American renewal (U. S. Patent Office, Decision of Commissioner of Patents, dated September 19, 1870).

been bought by an American group interested in the Kelly process at about this time,"⁸³ and Bessemer's American rights had also been sold to an American group that included Alexander Lyman Holley,⁸⁴ who had long been associated with Zerah Colburn, another American engineer. Colburn, who subsequently (1866) established the London periodical *Engineering* and is regarded as one of the founders of engineering journalism, was from 1862 onward a frequent contributor to other trade papers in London. Colburn's article of 1864⁸⁵ seems to have been of some importance to Mushet, who, in the prospectus of the Titanic Steel and Iron Company, Ltd., issued soon after, brazenly asserted⁸⁶ that, "by the process of Mr. Mushet especially when in combination with the Bessemer process, steel as good as Swedish steel" would be produced at £6 per ton. Mushet may have intended to invite a patent action, but evidently Bessemer could now more than ever afford to ignore the "sage of Coleford."

The year 1865 saw Mushet less provocative and more appealing; as for instance: "It was no fault of Mr. Bessemer's that my patent was lost, but he ought to acknowledge his obligations to me in a manly, straightforward manner and this would stamp him as a great man as well as a great inventor."⁸⁷

But Bessemer evidently remained convinced of the security of his own patent position. In an address before the British Association at Birmingham in September 1865 he made his first public reply to Mushet.⁸⁸ In his long series of patents Mushet had attempted to secure

almost every conceivable mode of introducing manganese into the metal. . . . Manganese and its compounds were so claimed under all imaginable conditions that if this series of patents could have been sustained in law, it would have been utterly impossible for [me] to have employed manganese with steel made by his process, although it was considered by the trade to be impossible to make steel from coke-made iron without it.

⁸³ See below, p. 45. The exact date of the purchase of Mushet's patent is not known.

⁸⁴ *Engineering*, 1882, vol. 33, p. 114. The deal was completed in 1863.

⁸⁵ *The Engineer*, 1864, vol. 18, pp. 405, 406.

⁸⁶ *Mining Journal*, 1864, vol. 34, pp. 77 and 94 (italics supplied). It has not yet been possible to ascertain if this company was successful. Mushet writes from this time on from Cheltenham, where the company had its offices. Research continues in this interesting aspect of his career.

⁸⁷ *Mining Engineer*, 1865, vol. 35, p. 86.

⁸⁸ *The Engineer*, 1865, vol. 20, p. 174.

The failure of those who controlled Mushet's batch of patents to renew them at the end of three years, Bessemer ascribed to the low public estimation to which Mushet's process had sunk in 1859, and he had therefore, "used without scruple any of these numerous patents for manganese without feeling an overwhelming sense of obligation to the patentee." He was now using ferromanganese made in Glasgow. Another alloy, consisting of 60 to 80 per cent of metallic manganese was also available to him from Germany.

This renewed publicity brought forth no immediate reply from Mushet, but a year later he was invited to read a paper before the British Association. A report on the meeting stated that in his paper he repeated his oft-told story, and that "he still thought that the accident (of the non-payment of the patent stamp duties) ought not to debar him from receiving the reward to which he was justly entitled." Bessemer, who was present, reiterated his constant willingness to submit the matter to the courts of law, but pointed out that Mushet had not accepted the challenge.⁸⁹

Three months later, in December 1866, Mushet's daughter called on Bessemer and asked his help to prevent the loss of their home: "They tell me you use my father's inventions and are indebted to him for your success." Bessemer replied characteristically:

I use what your father has no right to claim; and if he had the legal position you seem to suppose, he could stop my business by an injunction tomorrow and get many thousands of pounds compensation for my infringement of his rights. The only result which followed from your father taking out his patents was that they pointed out to me some rights which I already possessed, but of which I was not availing myself. Thus he did me some service and even for this unintentional service, I cannot live in a state of indebtedness. . . .

With that he gave Miss Mushet money to cover a debt for which distraint was threatened.⁹⁰ Soon after this action, Bessemer made Mushet a "small allowance" of £300 a year. Bessemer's reasons for making this payment, he describes as follows: "There was a strong desire on my part to make him (Mushet) my debtor rather than the reverse, and the payment had other advantages: the press at that time was violently attacking my patent and there was the chance that if any of my licensees were thus induced to resist my claims, all the rest might follow the example."⁹¹

⁸⁹ *Mining Engineer*, 1867, vol. 16, p. 147.

⁹⁰ Bessemer, *op. cit.* footnote 1, p. 294.

⁹¹ *Id.*

Mushet's Titanic Steel and Iron Company was liquidated in 1871 and its principal asset, "R. Mushet's special steel," that is, his tungsten alloy tool metal, was taken over by the Sheffield firm of Samuel Osborn and Company. The royalties from this, with Bessemer's pension seem to have left Mushet in a reasonably comfortable condition until his death in 1891;⁹² but even the award of the Bessemer medal by the Iron and Steel Institute in 1876 failed to remove the conviction that he had been badly treated. One would like to know more about the politics which preceded the award of the trade's highest honor. Bessemer at any rate was persuaded to approve of the presentation and attended the meeting. Mushet himself did not accept the invitation, "as I may probably not be then alive."⁹³ The President of the Institute emphasized the present good relations between Mushet and Bessemer and the latter recorded that the hatchet had "long since" been buried. Yet Mushet continued to

brood over the injustice done to him and eventually recorded his story of the rise and progress of the "Bessemer-Mushet" process in a pamphlet⁹⁴ written apparently without reference to his earlier statements and so committing himself to many inconsistencies.

William Kelly's "Air-boiling" Process

An account of Bessemer's address to the British Association was published in the *Scientific American* on September 13, 1856.⁹⁵ On September 16, 1856, Martien filed application for a U. S. patent on his furnace and Mushet for one on the application of his triple compound to cast iron "purified or decarbonized by the action of air blown or forced into . . . its particles while it is in a molten . . . state."⁹⁶

⁹⁴ Robert Mushet, *The Bessemer-Mushet process*, Cheltenham, 1883.

⁹⁵ *Scientific American*, 1856, vol. 12, p. 6.

⁹⁶ U. S. patent 17389, dated May 26, 1857. Martien's U. S. patent was granted as 16690, dated February 24, 1857.

⁹² See Fred M. Osborn, *The story of the Mushets*, London, 1852.

⁹³ *Journal of the Iron and Steel Institute*, 1876, p. 3.

W. Kelly
Manuf. of Iron & Steel.
No 17,628. Patented June 23, 1857.

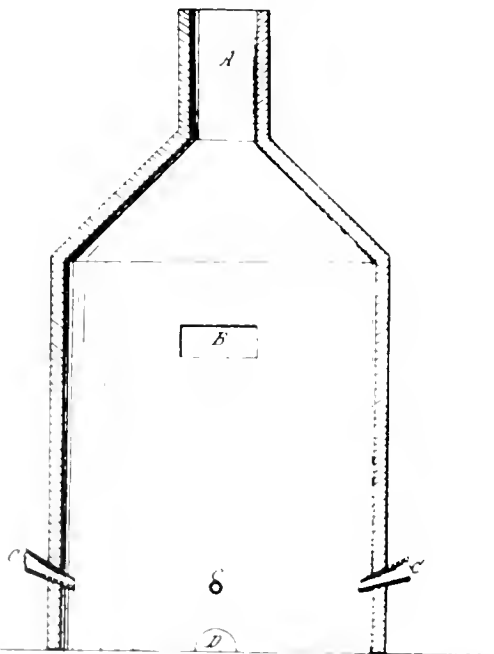


FIGURE 2. ONLY KNOWN DESIGN FOR KELLY'S AIR-BOILING FURNACE. FROM U. S. PATENT 17628. "A" is "the flue to carry off the carbonic gas formed in decarbonizing the iron."

"B" is the port through which the charge of fluid iron is received. "C" and "C'" are the tuyères, and "D" is the tap hole for letting out the refined metal.

Mushet, by this time, had apparently decided to generalize the application of his compound instead of citing its use in conjunction with Martien's process, or, as he put it, he had been obliged to do for his English specification by the Lbw Vale Iron Works.

The discussion in the *Scientific American*, which was mostly concerned with Martien's claim to priority, soon evoked a letter from William Kelly. Writing under date of September 30, 1856, from the Suwanee Iron Works, Eddyville, Kentucky, he claimed to have started "a series of experiments" in November 1851 which had been witnessed by hundreds of persons and "discussed amongst the ironmasters, etc., of this section, all of whom are perfectly familiar with the whole principle . . . as discovered by me nearly five years ago." A number of English puddlers had visited him to see his new process. "Several of them have since returned to England and may have spoken of my invention there." Kelly expected "shortly to have the invention perfected and bring it before the public."⁹⁷

Bessemer's application for an American patent was granted during the week ending November 18, 1856, and Kelly began his interference proceedings sometime before January 1857.⁹⁸

Kelly's witnesses were almost wholly from the ranks of employees or former employees. The only exception was Dr. Alfred H. Champion, a physician of Eddyville. Dr. Champion describes a meeting in the fall of 1851 with "two or three practical Ironmasters and others" at which Kelly described his process and invited all present to see it in operation. He stated:

The company present all differed in opinion from Mr. Kelly and appealed to me as a chemist in confirmation of their doubts. I at once decided that Mr. Kelly was correct in his Theory and then went on to explain the received opinion of chemists a century ago on this subject, and the present received opinion which was in direct confirmation of the novel theory of Mr. Kelly. I also mentioned the analogy of said Kelly's process in decarbonising iron to the process of decarbonising blood in the human lungs.

⁹⁷ *Scientific American*, 1856, vol. 12, p. 43, Kelly's suggestion of piracy of his ideas was later enlarged upon by his biographer John Newton Boucher, *William Kelly. A true history of the so-called Bessemer process*, Greensburg, Pennsylvania, 1924.

⁹⁸ *Ibid.*, p. 82. Kelly's notice of his intention to take testimony was addressed to Bessemer on January 12, 1857. See papers on "Interference, William Kelly vs. Henry Bessemer Decision April 13, 1857," U. S. Patent Office Records. Quotations below are from this file, which is now permanently preserved in the library of the U. S. Patent Office.

The Doctor did not say specifically if he or any of the "company" went to see the process in operation.

Kelly obtained affidavits from another seventeen witnesses. Ten of these recorded their recollections of experiments conducted in 1847. Five described the 1851 work. Two knew of or had seen both. One of the last group was John B. Evans who became forge manager of Kelly's Union Forge, a few miles from Suwanee. This evidence is of interest since a man in his position should have been in a position to tell something about the results of Kelly's operations in terms of usable metal. Unfortunately, he limits himself to a comment on the metal which had chilled around a tuyère which had been sent back to the Forge ("it was partly malleable and partly refined pig-iron") and to an account of a conversation with others who had worked some of Kelly's "good wrought iron" made by the new process.

Only one of the witnesses (William Soden) makes a reference to the phenomenon which is an accompaniment of the blowing of a converter: the prolonged and violent emission of sparks and flames which startled Bessemer in his first use of the process⁹⁹ and which still provides an exciting, if not awe-inspiring, interlude in a visit to a steel mill. Soden refers, without much excitement, to a boiling commotion, but the results of Kelly's "air-boiling" were, evidently, not such as to impress the rest of those who claimed to have seen his furnace in operation. Only five of the total of eighteen of the witnesses say that they witnessed the operations. Soden, incidentally, knew of seven different "air-boiling" furnaces, some with four and some with eight tuyères, but he also neglected to report on the use of the metal.

As is well known, Kelly satisfied the Acting Commissioner that he had "made this invention and showed it by drawings and experiment as early as 1847," and he was awarded priority by the Acting Commissioner's decision of April 13, 1857, and U. S. Patent 17628 was granted him as of June 23, 1857. The *Scientific American* sympathized with Bessemer's realization that his American patent was "of no more value to him than so much waste paper" but took the opportunity of chastising Kelly for his negligence in not securing a patent at a much earlier date and complained of a patent system which did not require an inventor to make known his discovery promptly. The journal advocated a "certain fixed time" after which such an inventor "should not be allowed to subvert

⁹⁹ Bessemer, *op. cit.* (footnote 7), p. 144.

a patent granted to another who has taken proper measures to put the public in possession of the invention.¹⁰⁰

Little authentic is known about Kelly's activities following the grant of his patent. His biographer¹⁰¹ does not document his statements, many of which appear to be based on the recollections of members of Kelly's family, and it is difficult to reconcile some of them with what few facts are available. Kelly's own account of his invention,¹⁰² itself undated, asserts that he could "refine fifteen hundredweight of metal in from five to ten minutes," his furnace "supplying a cheap method of making run-out metal" so that "after trying it a few days we entirely dispensed with the old and troublesome run-out fires."¹⁰³ This statement suggests that Kelly's method was intended to do just this; and it is not without interest to note that several of his witnesses in the Interference proceedings, refer to bringing the metal "to nature," a term often used in connection with the finery furnace. If this is so, his assumption that he had anticipated Bessemer was based on a misapprehension of what the latter was intending to do, that is, to make steel.

This statement leaves the reader under the impression that the process was in successful use. It is to be contrasted with the statement quoted above (page 43), dated September 1856, when the process had, clearly, not been perfected. In this connection, it should be noted that in the report on the Suwanee Iron Works, included in *The iron manufacturer's guide*,¹⁰⁴ it is stated that "It is at this furnace that Mr. Kelly's process for refining iron in the hearth has been most fully experimented upon."

¹⁰⁰ *Scientific American*, 1857, vol. 12, p. 341.

¹⁰¹ Boucher, *op. cit.* (footnote 97).

¹⁰² U. S. Bureau of the Census, *Report on the manufacturers of the United States at the tenth census (June 1, 1880) . . . , Manufacture of iron and steel*, report prepared by James M. Swank, special agent, Washington, 1883, p. 124. Mr. Swank was secretary of the American Iron and Steel Association. This material was included in his *History of the manufacture of iron in all ages*, Philadelphia, 1892, p. 397.

¹⁰³ *Ibid.*, p. 125. The run-out fire (or "finery" fire) was a charcoal fire "into which pig-iron, having been melted and partially refined in one fire, was run and further refined to convert it to wrought iron by the Lancashire hearth process," according to A. K. Osborn, *An encyclopaedia of the iron and steel industry*, New York, 1956.

¹⁰⁴ J. P. Lesley, *op. cit.* (footnote 39), p. 129. The preface is dated April 1, 1857. The data was largely collected by Joseph Leley of Philadelphia, brother of the author, during a tour of several months. Since Suwanee production is given for 44 weeks only (of 1857 . . . , through November 4 or 5, 1857) it is concluded that Lesley's visit was in the last few weeks of 1857.

A major financial crisis affected United States business in the fall of 1857. It began in the first week of October and by October 31 the *Economist* (London) reported that the banks of the United States had "almost universally suspended specie payment."¹⁰⁵ Kelly was involved in this crisis and his plant was closed down. According to Swank,¹⁰⁶ some experiments were made to adapt Kelly's process to need of rolling mills at the Cambria Iron Works in 1857 and 1858, Kelly himself being at Johnstown, at least in June 1858. That the experiments were not particularly successful is suggested by the lack of any American contributions to the correspondence in the English technical journals. Kelly was not mentioned as having done more than interfere with Bessemer's first patent application. The success of the latter in obtaining patents¹⁰⁷ in the United States in November 1856, covering "the conversion of molten crude iron . . . into steel or malleable iron, without the use of fuel . . ." also escaped the attention of both English and American writers.

It was not until 1861 that the question arose as to what happened to Kelly's process. The occasion was the publication of an account of Bessemer's paper at the Sheffield meeting of the (British) Society of Mechanical Engineers on August 1, 1861. Accepting the evidence of "the complete industrial success" of Bessemer's process, the *Scientific American*¹⁰⁸ asked: "Would not some of our enterprising manufacturers make a good operation by getting hold of the [Kelly] patent and starting the manufacture of steel in this country?"

There was no response to this rhetorical question, but a further inquiry as to whether the Kelly patent "could be bought"¹⁰⁹ elicited a response from Kelly. Writing from Hammondsville, Ohio, Kelly¹¹⁰ said, in part:

I would say that the New England states and New York would be sold at a fair rate . . . I removed from Kentucky

¹⁰⁵ *Economist* (London), 1857, vol. 15, pp. 1129, 1209.

¹⁰⁶ Swank, *op. cit.* (footnote 42), p. 125. John Fritz, in his *Autobiography* (New York, 1912, p. 162), refers to experiments during his time at Johnstown, *i.e.*, between June 1854 and July 1860. *The iron manufacturer's guide* (see footnote 104) also refers to Kelly's process as having "just been tried with great success" at Cambria.

¹⁰⁷ U. S. patents 16082, dated November 11, 1856, and 16083, dated November 18, 1856. Bessemer's unsuccessful application corresponded with his British patent 2321, of 1855 (see footnote 98).

¹⁰⁸ *Scientific American*, 1861, new ser., vol. 5, pp. 148-153.

¹⁰⁹ *Ibid.*, p. 310.

¹¹⁰ *Ibid.*, p. 343.

about three years ago, and now reside at New Salisbury about three miles from Hammondsville and sixty miles from Pittsburg. Accept my thanks for your kind efforts in endeavoring to draw the attention of the community to the advantages of my process.

This letter suggests that the Kelly process had been dormant since 1858. Whether or not as a result of the publication of this letter, interest was resumed in Kelly's experiments. Captain Eber Brock Ward of Detroit and Z. S. Durfee of New Bedford, Massachusetts, obtained control of Kelly's patent. Durfee himself went to England in the fall of 1861 in an attempt to secure a license from Bessemer. He returned to the United States in the early fall of 1862, assuming that he was the only "citizen of the United States" who had even seen the Bessemer apparatus.¹¹¹

In June, 1862, W. F. Durfee, a cousin of Z. S. Durfee, was asked by Ward to report on Kelly's process. The report¹¹² was unfavorable. "The description of [the apparatus] used by Mr. Kelly at his abandoned works in Kentucky satisfied me that it was not suited for an experiment on so large a scale as was contemplated at Wyandotte [Detroit]." Since it was "confidently expected that Z. S. Durfee would be successful in his efforts to purchase [Bessemer's patents], it was thought only to be anticipating the acquisition of property rights . . . to use such of his inventions as best suited the purpose in view."

Thus the first "Bessemer" plant in the United States came into being without benefit of a license and supported only by a patent "not suited" for a large experiment. Kelly seems to have had no part in these developments. They took some time to come to formation. Although the converter was ready by September 1862, the blowing engine was not completed until the spring of 1864 and the first "blow" successfully made in 1864. It may be no more than a coincidence that the start of production seems to have been impossible before the arrival in

this country of a young man, E. M. Hart, who had been trained in Bessemer operations at the plant of the Jackson Brothers at St. Saurin near Bordeaux, France. The Jacksons had become Bessemer's partners in respect of the French rights; and the recruitment of Hart suggests the possibility that it was from this French source that Z. S. Durfee obtained his initial technical data on the operation of the Bessemer process.¹¹³

During the organization of the plant at Wyandotte, Kelly was called back to Cambria, probably by Daniel J. Morrell, who, later, became a partner with Ward and Z. S. Durfee in the formation of the Kelly Pneumatic Process Company.¹¹⁴ We learn from John E. Fry,¹¹⁵ the iron moulder who was assigned to help Kelly, that

in 1862 Mr. Kelly returned to Johnstown for a crucial, and as it turned out, a final series of experiments by him with a rotative [Bessemer converter] *made abroad and imported for his purpose*. This converter embodied in its materials and construction several of Mr. Bessemer's patented factors, of which, up to the close of Mr. Kelly's experiments above noted, he seemed to have no knowledge or conception. And it was as late as on the occasion of his return in 1862, to operate the experimental Bessemer converter, that he first recognized, by its adoption, the necessity for or the importance of any after treatment of, or additions required by the blown metal to convert it into steel.

Fry later asserted¹¹⁶ that Kelly's experiments in 1862 were simply attempts to copy Bessemer's methods. (The possibility is under investigation that the so-called "pioneer converter" now on loan to the U. S. National Museum from the Bethlehem Steel Company, is the converter referred to by Fry.)

William Kelly, in effect, disappeared from the record until 1871 when he applied for an extension of his patent of June 23, 1857. The application was opposed (by whom, the record does not state) on the grounds that the invention was not novel when it was originally issued, and that it would be against the public interest to extend its term. The Commissioner

¹¹¹ His claim is somewhat doubtful. Alexander Lyman Holley, who was later to be responsible for the design of most of the first Bessemer plants in the United States had been in England in 1859, 1860, and 1862. In view of his interest in ordnance and armor, it is unlikely that Bessemer could have escaped his alert observation. His first visit specifically in connection with the Bessemer process appears to have been in 1863, but he is said to have begun to interest financiers and ironmasters in the Bessemer process after his visit in 1862 (*Engineering*, 1882, vol. 33, p. 115).

¹¹² W. F. Durfee: "An account of the experimental steel works at Wyandotte, Michigan," *Transactions of the American Society of Mechanical Engineers*, 1884, vol. 6, p. 40 ff.

¹¹³ Research in the French sources continues. The arrival of E. M. Hart at Boston is recorded as of April 1, 1864, his ship being the SS *Arctur* out of Liverpool, England. Archives of the United States, card index of passenger arrivals 1841-1891 list No. 391.

¹¹⁴ Swank, *loc. cit.*, footnote 423, p. 409.

¹¹⁵ *Journal of the Detroit Society of Engineers*, 1894 (articles supplied). Mr. Fry was at the Cambria Iron Works from 1858 until after 1882.

¹¹⁶ *Engineering*, 1896, vol. 61, p. 615.

and that, on the first question, it was settled practice of the Patent Office not to reconsider former decisions on questions of fact; the novelty of Kelly's invention had been re-examined when the patent was reissued in November 1857. Testimony showed that the patent was very valuable; and that Kelly "had been untiring in his efforts to introduce it into use but the opposition of iron manufacturers and the amount of capital required prevented him from receiving anything from his patent until within very few years past." Kelly's expenditures were shown to have amounted to \$11,500, whereas he had received only \$2,400. Since no evidence was filed in support of the public interest aspect of the case, the Commissioner found no substantial reason for denying the extension; indeed "very few patentees are able to present so strong grounds for extension as the applicant in the case."

In a similar application in the previous year, Bessemer had failed to win an extension of his U. S. patent 16082, of November 11, 1856, for the sole reason that his British patent with which it had been made co-terminal had duly expired at the end of its fourteen years of life, and it would have been inequitable to give Bessemer protection in the United States while British iron-masters were not under similar restraint. But if it had not been for this consideration, Bessemer "would be justly entitled to what he asks on this occasion." The Commissioner¹¹⁸ observed: "It may be questioned whether [Bessemer] was first to discover the principle upon which his process was founded. But we owe its reduction to practice to his untiring industry and perseverance, his superior skill and science and his great outlay."

Conclusions

Martien was probably never a serious contender for the honor of discovering the atmospheric process of making steel. In the present state of the record, it is not an unreasonable assumption that his patent was never seriously exploited and that the Ebbw Vale Iron Works hoped to use it, in conjunction with the Mushet patents, to upset Bessemer's patents.

The position of Mushet is not so clear, and it is hoped that further research can eventually throw a

clearer light on his relationship with the Ebbw Vale Iron Works. It may well be that the "opinion of metallurgists in later years"¹¹⁹ is sound, and that both Mushet and Bessemer had successfully worked at the same problem. The study of Mushet's letters to the technical press and of the attitude of the editors of those papers to Mushet suggests the possibility that he, too, was used by Ebbw Vale for the purposes of their attacks on Bessemer. Mushet admits that he was not a free agent in respect of these patents, and the failure of Ebbw Vale to ensure their full life under English patent law indicates clearly enough that by 1859 the firm had realized that their position was not strong enough to warrant a legal suit for infringement against Bessemer. Their purchase of the Uchatius process and their final attempt to develop Martien's ideas through the Parry patents, which exposed them to a very real risk of a suit by Bessemer, are also indications of the politics in the case. Mushet seems to have been a willing enough victim of Ebbw Vale's scheming. His letters show an almost presumptuous assumption of the mantle of his father; while his sometimes absurd claims to priority of invention (and demonstration) of practically every new idea in the manufacturing of iron and steel progressively reduced the respect for his name. Bessemer claims an impressive array of precedents for the use of manganese in steel making and, given his attitude to patents and his reliance on professional advice in this respect, he should perhaps, be given the benefit of the doubt. A dispassionate judgment would be that Bessemer owed more to the development work of his Swedish licensees than to Mushet.

Kelly's right to be adjudged the joint inventor of what is now often called the Kelly-Bessemer process is questionable.¹²⁰ Admittedly, he experimented in the treatment of molten metal with air blasts, but it is by no means clear, on the evidence, that he got beyond the experimental stage. It is certain that he never had the objective of making steel, which was Bessemer's primary aim. Nor is there evidence that his process was taken beyond the experimental stage by the Cambria Works. The rejection of his "apparatus" by W. F. Durfee must have been based, to some extent at least, upon the Johnstown trials. There are strong

¹¹⁸ See U. S. Patent Office, Decision of Commissioner of Patents dated June 15, 1871.

¹¹⁹ U. S. Patent Office, Decision of Commissioner of Patents dated February 12, 1870.

¹¹⁹ William F. Jeans, *The creators of the age of steel*, London, 1884.

¹²⁰ Bessemer dealt with Kelly's claim to priority in a letter to *Engineering*, 1896, vol. 61, p. 367.

grounds then, for agreeing with one historian¹²¹ who concludes:

The fact that Kelly was an American is evidently the principal reason why certain popular writers have made much of an invention that, had not Bessemer developed his process, would never have attracted notice. Kelly's patent proved very useful to industrial interests in this country as a bargaining weapon in negotiations with the Bessemer group for the exchange of patent rights.

¹²¹ Louis C. Hunter, "The heavy industries since 1860," in H. F. Williamson (editor), *The growth of the American economy*, New York, 1944, p. 469.

Kelly's suggestion¹²² that some British puddlers may have communicated his secret to Bessemer can, probably, never be verified. All that can be said is that Bessemer was not an ironman; his contacts with the iron trade were, so far as can be ascertained, non-existent until he himself invaded Sheffield. So it is unlikely that such a secret would have been taken to him, even if he were a well-known inventor.

¹²² Later developed into a dramatic story by Boucher, *op. cit.*, footnote 97.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY

PAPER 4

THE AUBURNDALE WATCH COMPANY

Edwin A. Battison

THE INVENTION	52
DEVELOPING THE INVENTION	53
THE NEW SPONSOR	57
SUCCESS AND FAILURE	64
THE LESSON	67

By Edwin A. Battison

THE AUBURNDALE WATCH COMPANY:

First American Attempt Toward the Dollar Watch

The life of the pioneer has always been arduous. Not all succeed, and many disappear leaving no trace on the pages of history. Here, painstaking search has uncovered enough of the record to permit us to review the errors of design and manufacture that brought failure to the first attempt to produce a really cheap pocket watch.

This paper is based on a study of the patent model of the Auburndale rotary and other products of the company in the collections of the National Museum, and of other collections, including that of the author. The study comprises part of the background research for the hall of timekeeping in the Museum of History and Technology.

THE AUTHOR: Edwin A. Battison is associate curator of mechanical and civil engineering, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.

THE IDEA OF A MACHINE-MADE WATCH with interchangeable parts had been in the minds of many men for a long time. Several attempts had been made to translate this conception into a reality. Success crowned the efforts of those working near Boston, Massachusetts, in the 1850's. The work done there formed the basis on which American watch making grew to such a point that by the 1870's watches of domestic manufacture had captured nearly all the home market and were reaching out and capturing foreign markets as well. In spite of this great achievement there remained a large untapped potential market for a watch which would combine the virtues of close time keeping and a lower selling price. Only a radical departure in design could achieve this. Rivalry between the several existing companies had already produced an irreducible minimum price on watches of conventional design.

The great obstacle to close rate in a modestly priced watch is the balance wheel. This wheel requires careful adjustment for temperature error and for poise. Of these two disturbing factors poise is the most annoying to the owner because lack of it makes the watch a very erratic timekeeper. A watch in which the parts are not poised is subject to a different rate for every position it is placed in. This position error, as it is called, can and often does cause a most erratic and unpredictable rate. Abraham-Louis Breguet, the celebrated Swiss-French horologist of Paris is credited with the invention, in 1801,¹ of his tourbillon, a clever way to circumvent this error.

His solution was to mount the escapement in a frame or "chariot" which revolved, usually once a

¹ Paul M. Chamberlain, *It's about time*, New York, 1947, p. 362.

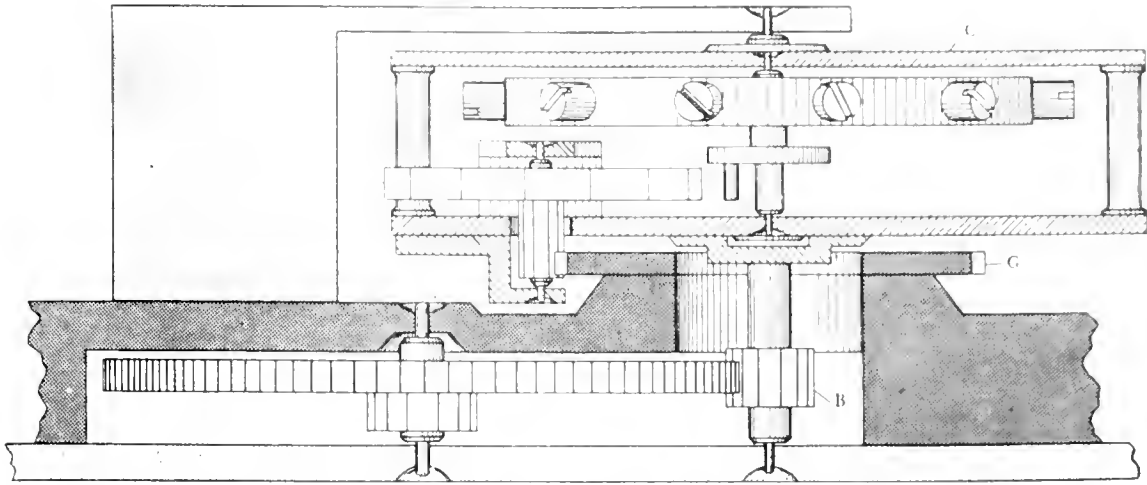


Figure 1.—BREGUET'S TOURBILLON. At C is shown the carriage which revolves with pinion B carrying the escapement and balance around the stationary wheel G. (After G. A. Baillie, *Watches, their history, decoration, and mechanism*, London, Methuen, n.d.)

minute, so that with each revolution all possible positions were passed through (fig. 1). This gave the watch an average rate which was constant except for variations within the period of revolution of the chariot. Only a very skillful workman could, however, work with the delicacy necessary to produce such a mechanism. The result was that few were made and these were so expensive that it continued to be more practical to poise the parts in a conventional movement. The idea of revolving the entire train of a watch, including the escapement, seems to have evolved surprisingly slowly from Breguet's basic invention of the revolving escapement. In constructing a watch wherein the entire train revolves, no such delicate or precise workmanship is required as in the tourbillon. Due to the longer train of gears involved the period of revolution is much slower. Position errors average out as certainly if not as frequently. In Bonniksen's "Karruef" watch of 1893² the duration of a cycle is 52.5 minutes³ while in the Auburndale Rotary which we are about to discuss the period of each revolution is 2½ hours.

The Invention

The patent model of Jason R. Hopkins' revolving watch, now in the U. S. National Museum,⁴ was not the first in which the entire train revolved but it was a very novel conception intended to reduce greatly

the number of parts usually associated with any watch. This may be seen from figures 2 and 3, where everything shown inside the ring gear revolves slowly as the main spring runs down. This spring is prevented from running down at its own speed by the train pinion seen in mesh with the ring gear. Through this pinion motion is imparted to the escape wheel and balance, where the rate of the watch is controlled. The balance, being planted at the center of revolution, travels around its own axis, as in the tourbillon, at the speed with which the entire train revolves around the barrel arbor. This arbor turns only during winding. No dial or dial gearing is shown in the patent or exists in the patent model. The patent merely says, casually, "By means of dial wheels the motion of the barrel may be communicated to hands and the time indicated in the usual manner." No fine finish or jeweling has been lavished on the model, the only jewels present being in the balance cock which was utilized as it came from its original watch with only minor modification to the shape of its foot. Apparently the balance wheel itself is also a relic of the same or a similar conventional watch. There is no jeweling in the escapement or on the other end of the balance staff. In spite of this the model runs very actively and will overbank if wound up very far. The beat of the escapement is two per second and the movement revolves once in 20 minutes.

There are two great faults in the model. First is the lack of an adequate bearing for the barrel to turn on. There is only one very short bearing a long way removed from the point of engagement between

² British patent 21421, granted January 21, 1893.
³ Chamberlain, *op. cit.* (footnote 1), pp. 229, 230.
⁴ Cat. no. 309025; U. S. patent 161513, July 20, 1875.

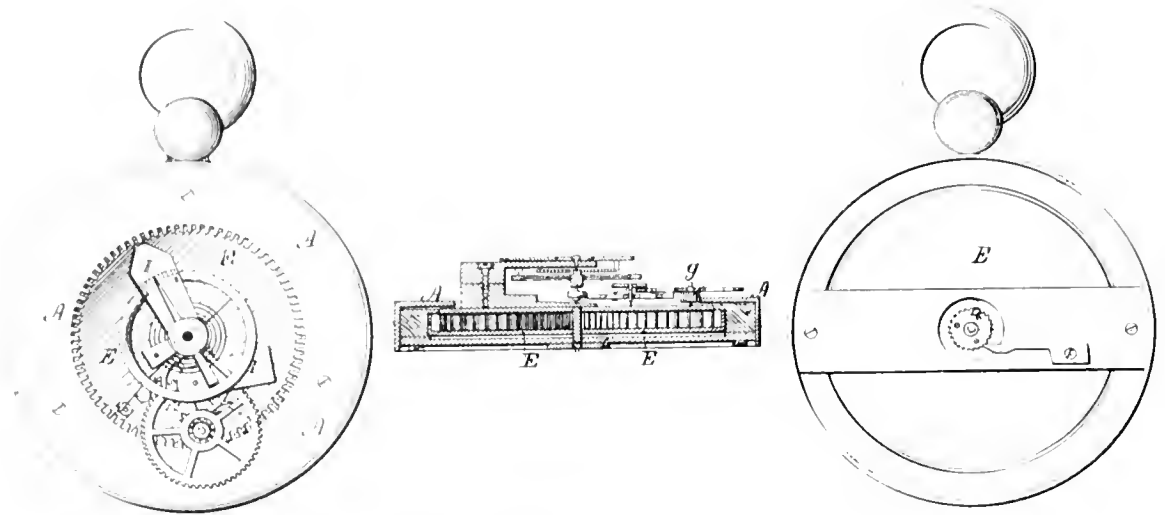


Figure 2. PATENT DRAWING OF THE HOPKINS WATCH. The mainspring barrel *E*, of a very large diameter in proportion to the diameter of the watch, occupies nearly the full diameter of the movement. The spring itself, narrower and much longer than usual, is made in the patent model by riveting two ordinary springs together end to end. Over this barrel and attached to the stationary frame of the watch is placed a large thin ring *A*, cut on its inner diameter with 120 teeth. Near its edge the barrel *E* carries a stud *g* on which runs a pinion of 10 in mesh with the ring gear *A*.

On this pinion is a wheel of 80 driving a pinion of 6 on the escape-wheel arbor. The 15-tooth escape wheel locks on a spring detent and gives impulse to the balance in one direction only, being a conventional chronometer escapement. The intermediate wheel and pinion, balance wheel, and balance cock have been adapted from a Swiss bar movement of the time.

the pinion and internal gear, and no adequate support is given the barrel, with the result that it tends to deflect from the ideal or true position and to bind. This condition is aggravated by the fact that the ring gear was made by cutting its teeth on an angle to the axis around which it is to revolve, using only a saw of appropriate width. The teeth were then rounded-up to form by hand in a separate operation which by its very nature means that the teeth are not exactly alike. This lack of uniformity of the ring gear coupled with an entirely inadequate bearing for the barrel contributes to rather erratic transfer of power. These irregular teeth would not, of course, be a factor in factory-made watches where suitable machinery would be available for the work.

The second fault is in the ratio between the time of one revolution and the number of revolutions necessary for a day's run. Three turns of the spring are, of course, required to run the watch for an hour, since the barrel and train revolve three times in that length of time. If we choose to have the watch run for 30 hours on a winding, and this leaves but a small safety

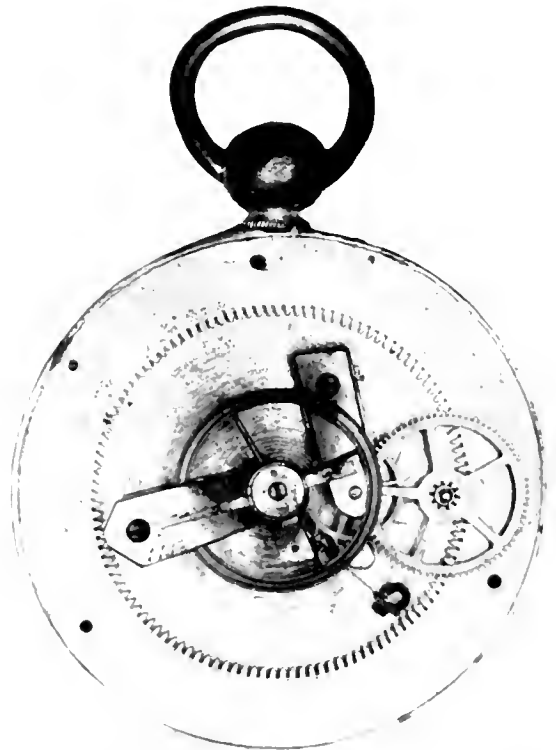


Figure 3. ORIGINAL PATENT MODEL OF THE HOPKINS WATCH, U. S. Patent 161513, July 20, 1875, now in the U. S. National Museum (*cat. no.* 309025).

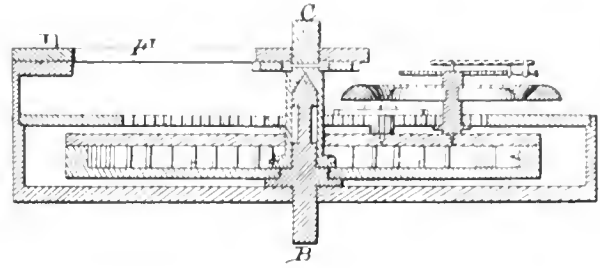
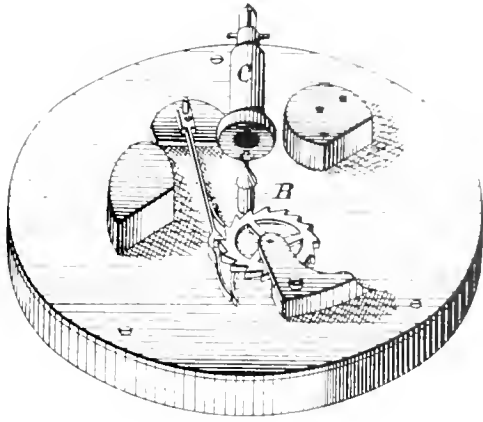


Figure 1. DRAWING FROM U. S. PATENT 165831 showing Hopkins' first design improvement, an arbor for the barrel and train to turn on and the balance displaced from center.

factor, then we see that this will require 90 turns of the main spring, a manifest impossibility in view of the space available.⁵

⁵ Those who have seen the Waterbury watch, which developed from this design, may be drawn to the conclusion that this explains why it took so long to wind the Waterbury. Such is not really the case; in the Waterbury the winding wheel (which is on the outer rim of the barrel) was nearly as large as the inside diameter of the case while the pinion engaging with it was of only nominal diameter. This meant that one turn of the winding crown wound the barrel a much smaller fraction of a revolution than in a watch of conventional design.

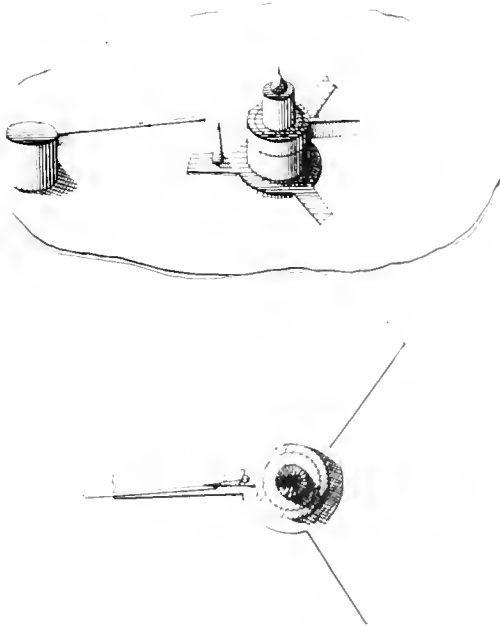


Figure 5. HOPKINS' BALANCE ARRESTING DEVICE, the subject of U. S. patent 165830. This and the device illustrated in figure 1 originally were submitted together to the Patent Office on June 6, 1875, and later were divided into two patents.

Probably no attempt was made to produce a finished and practical watch at this time, although Hopkins, the inventor, was an actual watchmaker as well as a retail jeweler, with premises virtually in the shadow of the Patent Office. He was a native of Maine⁶ and had been established in Washington since 1863, or perhaps some time in 1862.⁷

Developing the Invention

Edward A. Locke had long been seeking a simple watch adapted to easy manufacture and a selling price of three to four dollars. While on a trip to Washington his attention was drawn to the Hopkins watch by William D. Colt of Washington.⁸ A result of this meeting appears to have been the issuance to Jason

⁶ District of Columbia death record 145,013.

⁷ Hopkins is not in the *Washington and Georgetown Directories* of 1860 or 1862, and 1861 was not available to check. Starting with 1863 he is listed each year through 1871. Starting with 1872 Boyd's *Directory of the District of Columbia*, lists Hopkins as a resident each year (including 1902, the year of his death at 84 years) except 1877, when he was out of the city in connection with the exploitation of his rotary watch patents. Carl W. Drepperd, *Hours of the Past in America* (Garden City, N.Y., 1947), in referring to Hopkins, says, "Lincoln, Me., 1840s-1850s; Bangor, Me., to 1862. Inventor of the Auburn Watch." Also manufactured pianos and clock cases.

⁸ Chas. S. Crossman, "A complete history of watch and clock making in America," *7th Annual Convention of the Watch and Clock Makers' Association*, January 1888, pp. 400-401. This history ran as a continuing series of short articles appearing over a period of years. In a sketch of the Waterbury Watch Co., Crossman gives the name as William D. Coates, a name not found in Boyd's *Directory of the District of Columbia* for 1878. The other directories I now contain the name of William D. Colt, a patent attorney.

R. Hopkins of two patents,⁹ in both of which half rights were assigned to William D. Colt. Patent 165831, relates to a barrel arbor for watches. The arbor will be seen (fig. 4) to consist of two parts, one telescoped within the other and the composite arbor *B-C* supported at each end by the frame of the watch. The patent text limits itself to a bare description of the arbor. In the light of what we have seen of the shortcomings of the original model, however, the patent drawings tell that much more had been accomplished on the general design of a more workable rotary watch.

A square on arbor *C* at the back of the watch permits winding the main spring, which attaches to the largest diameter of *C*, a ratchet or winding click being supplied just under support *F*. The inner or front part *B* of the composite arbor projects from the front of the movement and revolves at the speed of the barrel arbor, which speed is not specified. Also, looking at the perspective view, we see that while the chronometer escapement has been retained, the balance has been placed eccentrically to make room for the center arbor. The balance now describes an orbit around the center of revolution. No driving train is shown, it being irrelevant to the patent, but there seems to be ample room for two intermediate wheels and their pinions between the escape wheel and the train cock boss, seen at the upper right in the perspective view of figure 4. Adding one more wheel and pinion to the train would have the effect of reducing the number of revolutions required of the spring barrel. We have seen from examination of the patent model of the Hopkins rotary that this was necessary not only to reduce the number of turns of the main spring and barrel but also to reduce the force transmitted to the escapement. There seems little reason from the foregoing observations and considerations to doubt that these modifications had been realized by the time of this patent. Again no dial gearing is shown. If the need for special gearing existed at this time it seems strange that it was not covered by patent as was done in the later patent¹⁰ assigned to William B. Fowle. The only way to avoid special gearing would be to revolve the barrel and train each hour so that the minute hand could travel with them as it travels with the center wheel in conventional watches. Once this condition was set up, the usual dial gearing would apply.

Companion patent 165830 (see fig. 5) covers a mechanism to prevent overbanking of the balance wheel, primarily of a chronometer escapement. This, of course, was aimed at making it possible to use the escapement in connection with a mainspring of greatly varying power. We have seen that this condition of uneven power existed in the first Hopkins watch. While the condition was greatly improved in the second model (seen in fig. 4), it was surely present to some extent, as it is associated with every spring. Overbanking protection may well have continued to be necessary, particularly if the gear ratio between escapement and barrel was low enough to permit hourly rotation of the barrel. The features covered by this patent were originally submitted as part of what later became patent 165831. Examination of the original manuscript patent file¹¹ shows that the patent application was separated into two on the

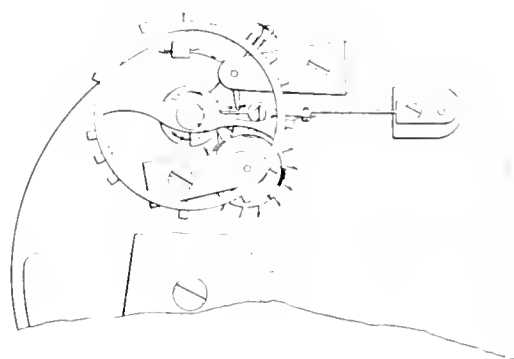


Figure 6. DRAWING FROM U. S. PATENT 179019 showing Hopkins' device to prevent the tripping of a chronometer escapement.

suggestion of the patent examiner, who pointed out that two distinct and separate mechanisms were involved, either of which could be used without the other.

These two patents, which actually started out as one, appear to represent the watch as it was when Hopkins went to Waterbury, Connecticut, where he again met Edward A. Locke. They submitted this improved watch model to the Benedict and Burnham Manufacturing Co., which advised not manufacturing it until it was further developed. Hopkins went with his watch from there to Boston, where he conferred with George Merritt who, like Locke, was interested

⁹ U. S. patents 165830 and 165831, granted July 20, 1875.

¹⁰ U. S. patent 186838, January 30, 1877.

¹¹ Patent file 165831, records of the Patent Office in the National Archives, Washington, D. C.

in getting into the manufacture of a low-priced watch, Merritt may have been the senior member of the Locke-Merritt team or may simply have had more faith than his associates in Hopkins and his watch. At any rate, he advanced expense money while further efforts at improvement were made.¹² Hopkins' absence from the *Washington city directory* of 1877 is perhaps explained by this work he was doing on his patent. While this was completed to Hopkins' satisfaction, it still fell short of Merritt's idea of practicality, and the latter abandoned the idea of manufacturing the watch;¹³ what had started out as a very simple watch of few parts grew, with every effort to make it

tion was made for the patent 17,809 to prevent overbanking. The cash book of William B. Fowle of Auburndale, Massachusetts,¹⁴ tells us that he bought half of William D. Colt's half-interest in the Hopkins rotary in March 1876, partly for cash but including a royalty on each watch made. Half this royalty was to go to Hopkins, a quarter to William D. Colt, and a quarter to William B. Fowle. Does patent 17,901, issued June 20, 1876, to Hopkins, who assigned it on June 10, 1876, to Fowle,¹⁵ represent the last improvement offered to Merritt? It covers a device actuated by a spur on a balance staff to lock the detent against tripping when in one position and to permit normal

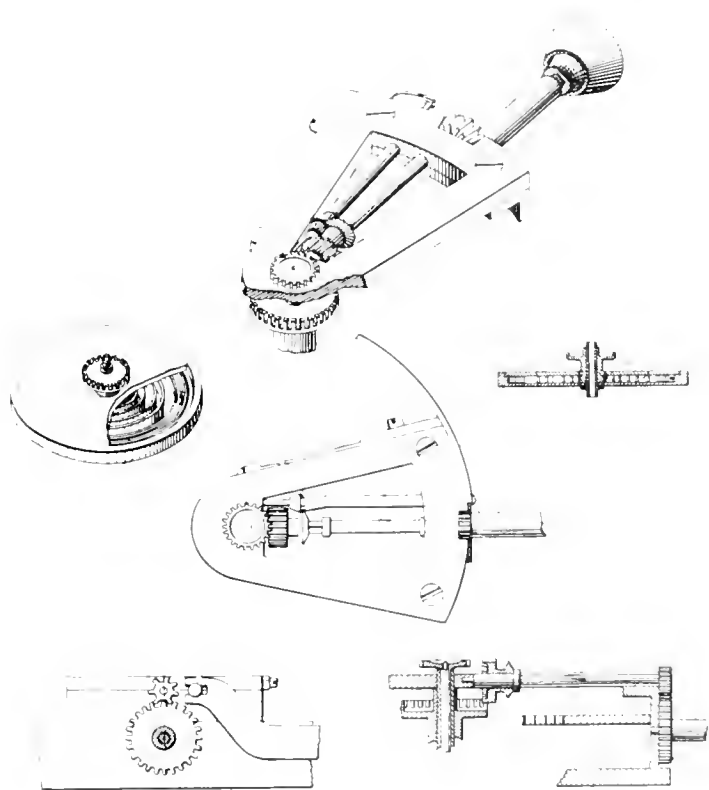


Figure 7. PART OF THE DRAWINGS FROM U. S. PATENT 186838, showing the winding and setting mechanism very nearly as it was applied in the Auburndale rotary.

workable, more and more complicated by involved and expensive detail. It appears that Hopkins did not possess the rare gift of improvement by simplification. This is a rare gift, and one seldom possessed by an individual very closely and intensely involved in the minute details of a given problem.

How long this period of development and experimentation required is unreported. It could hardly have started before early June of 1875, when applica-

tion of the chronometer escapement when in the other position—see fig. 6). Another patent applied

¹² Crossman, *op. cit.* (footnote 8), January 1888, p. 32.

¹³ *Ibid.*, p. 33.

¹⁴ William B. Fowle's "Cash book," commenced January 7, 1873, and closed February 21, 1882, plus "Cash Book #2—Leaves 1 to 20 inclusive. All that were used up to my failure on August 3, 1883," are in the author's possession. They contain many entries on the "Watch Adventure" and later "Aub Watch Co." mixed in with other entries referring to everything from killing pigs to extensive stock, bond, and real estate transactions.

¹⁵ U. S. Patent Office digest of assignments, vol. H V, p. 75, stored at Framcoma, Virginia. Accession no. 57 A 3 03.

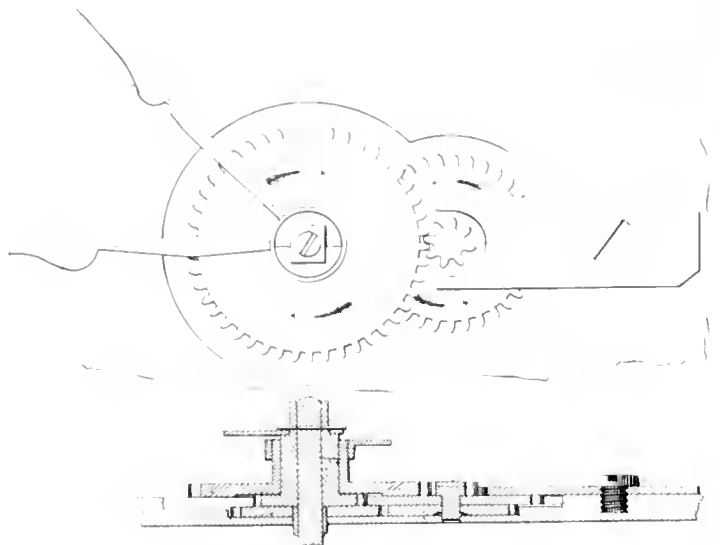


Figure 8. REMAINING DRAWINGS FROM U. S. PATENT 186838, showing the dial gearing used in the Auburndale rotary.

for on January 12, 1876, was in prospect and finally issued as no. 186838 on January 30, 1877, assigned to William B. Fowle on November 21, 1876.¹⁶ This is much the most practical and useful patent in the series. A comparison of these (see figs. 7 and 8) with the Auburndale rotary watch (see fig. 9) shows a remarkable similarity between the inventor's conception and the product eventually manufactured. A

¹⁶ *Ibid.*, p. 76.



Figure 9. AUBURNDALE ROTARY WATCH MOVEMENT. (In the author's collection.)

practical center arbor to support and guide the entire rotating mechanism is here combined with a stem-winding and lever-setting mechanism and dial gearing in a well thought out arrangement.

Here, where the story of the Hopkins watch diverges from the interests who later brought out the rival Waterbury watch, it seems appropriate to call the reader's attention to the basic points of novelty and merit in the Hopkins watch which carried over to what became the Waterbury, somewhat as an hereditary characteristic passes from generation to generation. Previous writers have realized that one of these watches led to the other and have grouped them together because of the rotating feature which they shared in common. Beyond this point they have treated the watches as though they had nothing in common. Actually several basic features of the Hopkins watch existed in both: the long narrow spring in a barrel approximately filling one side of the watch case, a train rotating in the center of the watch and driven by a planetary pinion in mesh with a gear fixed to the stationary part of the watch, a slow beat escapement, and probably the hourly rotation of the train and escapement. When these details appeared in the first watches manufactured for Messrs. Locke and Merritt by the Benedict and Burnham Manufacturing Co. and later the Waterbury Watch Co., they were vastly changed in detail and much better adapted to mass production, although still basically the same.

The story of Hopkins' rotary watch now enters an entirely new setting with new financial backing which, however, had no apparent experience or background

Figure 10. WILLIAM B. FOWLE, sponsor of the Auburndale Watch Co., after an engraving in S. F. Smith, *History of Newton, Massachusetts* (Boston, 1886).

in mechanical work, much less watch manufacturing. Those with watchmaking experience who were brought into this new organization unquestionably did their best, based on past experience confined to conventional watches of much higher grade. Judging from the products turned out, however, they had great difficulty in making a clean break with their past and in producing a satisfactory low-priced watch of new and radical concept. The market for watches, which had been depressed, was at this time reviving a little. The *Newton Journal*,¹⁷ referring to the American Watch Co. at Waltham reported: "The hands employed in the caseroom and the machinists have been called in. All the works are to be started the first of September."

The New Sponsor

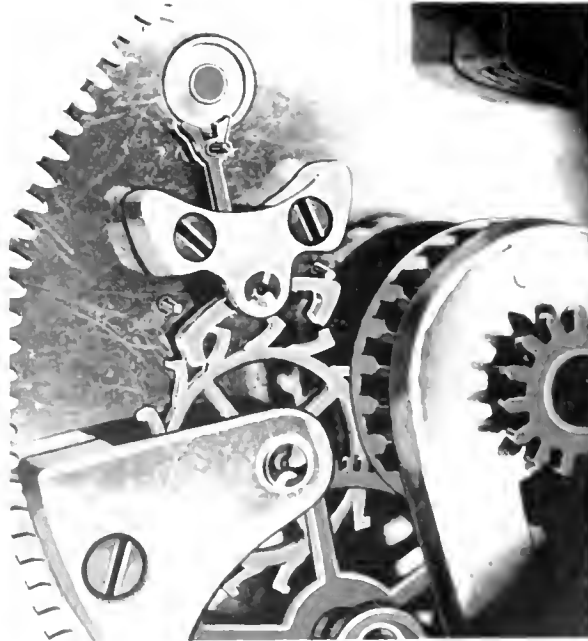
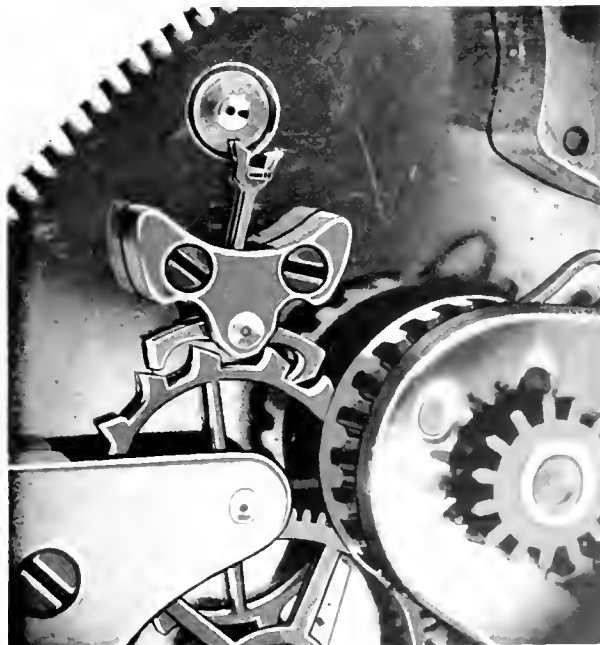
William Bentley Fowle (fig. 10), new partner with Hopkins and Colt in the watch, was born in Boston, Massachusetts on July 27, 1826. His father, William B. Fowle, Senior, a well-known Boston teacher and

¹⁷ August 26, 1876, p. 2., under the heading of Waltham Items, "Signs of a revival of business at the Watch Works in Waltham."



Wm B. Fowle

Figure 11.— THE TWO LEVER ESCAPIMENTS USED IN THE AUBURNDALE ROTARY. Note, in addition to the escapement, the absence of banking pins and the metal balance jewel in the escapement at the left, which is from watch No. 176. (Both watches in the author's collection.)



educator, had variously been a bookseller and conductor of a "Female Monitorial School."¹⁸ The junior William B. Fowle we have first located as a ticket master with the Boston and Worcester Railroad in 1848,¹⁹ and he retained this listing in the directory through 1851. Starting in 1852 and continuing through 1862, with no indication of employer or occupation, he had an office at 9 Merchants Exchange. In 1860 and 1862 he was a member of the Boston Common Council, and was president of that body in 1865. In 1862, after the second battle of Bull Run, he raised an infantry company for the 43rd Massachusetts Volunteers and was mustered in, September 24, 1862, with the rank of captain. From December 7, 1862, to March 4, 1863, he was commandant of the military post at Beaufort, North Carolina. He then reported to his regiment. On June 24, 1863, he was left sick at New Bern, North Carolina, by his company bound for Fortress Monroe. On July 21 he rejoined his company at Boston, Massachusetts, in time to be mustered out on July 30 at the expiration of his nine months' enlistment.²⁰

In the 1864 *Boston directory* we find him listed as treasurer of the Bear Valley Coal Co., and the North Mountain Coal Co., with an office at 38 City Exchange. This association with the coal business continued with changes unimportant to our story through the directories until 1877, in which year the name is dropped from the *Boston directory*, not to reappear until the directory of 1880, where he is listed at "Herald Building, watches and timers." This was apparently the sales office. The *Newton directory* of 1877 drops its previous listing of coal after Mr. Fowle's name and first mentions the Auburndale Watch Co.²¹ In 1866 Mr. Fowle established his home, Tanglewood, in Auburndale, a village in Newton not far from his boyhood home at West Newton and on the bank of the Charles River about two miles upstream from the Waltham Watch Co. He served the town of Newton as selectman from 1869 through 1871, was an alderman in 1877, and mayor in 1878 and 1879.²²

¹⁸ *Stamp on's Boston directory*, 1840.

¹⁹ *Adams' new directory of the City of Boston*, 1847-48, 1849-50, 1851.

²⁰ Records of Veterans Administration, pension application 666975, National Archives, Washington, D. C.

²¹ The *Newton directory* at this time was issued biennially on odd numbered years.

²² S. E. Smith, *History of Newton, Massachusetts*, Boston 1880, p. 833.

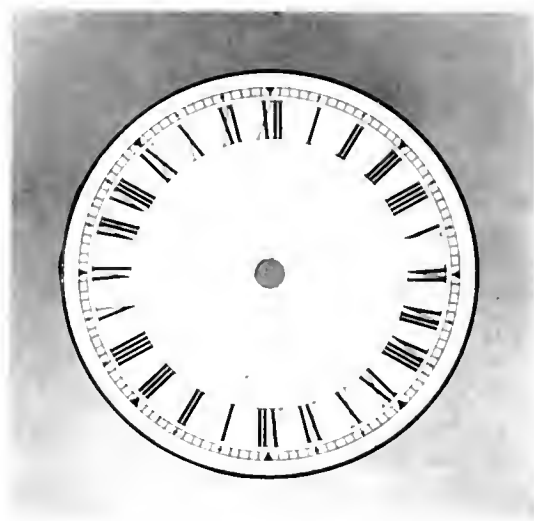


Figure 12. A 24-HOUR DIAL for the rotary watch. (In the author's collection.)

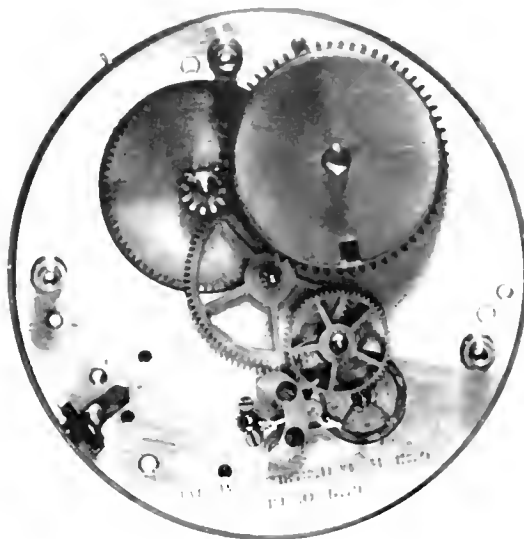
William Atherton Wales of New York is credited with introducing Mr. Fowle to the Hopkins watch. No clue has come to light on what connection there was between Hopkins and Wales, who had been a partner in the large watch-importing house of Giles, Wales and Co., in New York and later a large stockholder in the United States Watch Co. of Marion, New Jersey, which had only ceased operation in 1874. A patent²³ had been issued to Fayette S. Giles of New York, the leading figure in the United States Watch Co., for an improvement in stem-winding watches. This had presumably been available to his company. In this winding mechanism a crown pinion driven by a clutch on the stem engages with a large ring gear, having 110 internal teeth, which in turn drives a gear on the barrel arbor. The author has seen no watch, except the patent model,²⁴ containing this device, but the pillar plate of many of the United States Watch Co. movements were cut out, apparently to receive this ring gear.

The expense of cutting so many internal teeth in steel seems reason enough to explain why this patent did not become the basis for all their stem-wound models. Steel is far more difficult to cut than brass, resulting in a much greater consumption of time and cutters, both of which represent money to the manufacturer. In the patent model these ring-gear teeth have been cut by a milling cutter which did not pass

²³ U. S. patent 65208, issued May 28, 1867, all rights assigned to Giles, Wales and Co., March 4, 1867 and recorded March 8, 1867, at U. S. Patent Office, fiber G9, p. 100.

²⁴ In the U. S. National Museum, cat. no. 309021.

Figure 13. THE AUBURNDALE TIMER with top plate, balance, and control mechanism removed to show the train. The conventional barrel has 66 teeth that drive a pinion on the so-called 10-minute staff. This staff carries on the dial end the pointer, which revolves in 10 minutes, as indicated on the dial. Also on this staff is an unspoked wheel of 80 driving the center, or minute, staff through a pinion of 8. In addition to the sweep hand (or hands in the case of the split model) indicating seconds up to a duration of one minute, there is a wheel of 80 driving a pinion of 8 on an intermediate staff. A wheel of 60 on this staff drives a pinion of 10 on the escape-wheel staff. A pointer on this last staff also carries the hand that indicates fractions of a second. (In the author's collection.)



through the ring and across the face of the teeth. This produced a gear somewhat resembling an internal bevel gear, one which could have only the merest contact with its mating pinion. To make a durable gear for this application it would be necessary to pass the cutter through the ring in line with the gear axis. This would require a special or, at least, radically modified gear-cutting machine with a cutter arbor shorter than the inside diameter of the gear. Into this short space the spindle bearings and means of driving the spindle would have to be crowded, along with the cutter. Hopkins faced a problem similar to this in cutting the ring gear for his watch, except that the brass gear needed for the rotary watch could be cut far more easily and quickly. This may be the link which brought Wales and the defunct United States Watch Co. into the Auburndale picture. Another plausible link between Fowle and Wales involves a patent²⁵ Wales received for a pulley. This, the now familiar device of interlocking conical sections so commonly used in variable speed V-belt drives, was assigned to G. E. Lincoln of Boston, Massachusetts. George E. Lincoln was treasurer of the Mammoth Vein Consolidated Coal Co. at Boston in 1865, with an office adjoining that of Fowle. In addition he boarded for many years at Auburndale,²⁶ and he apparently owned the buildings about to be converted into a watch factory. Thus we see that Lincoln may very well have been the one who brought Fowle and Wales together.

William B. Fowle's cash book shows, on July 14, 1876, payment to Geo. E. Lincoln "For large building

²⁵ U. S. patent 179746, issued July 11, 1876.

²⁶ *Boston directory*, 1865 through 1872.

used \$200" and "For small building used \$50." On July 21 is an entry "Milo Lucas bal. of Building Contract \$1605.25." These with an entry on the preceding June 30, "Milo Lucas on a c Contract for Building" seem, with a July 25 entry "W. E. C. Fowler, Painting Factory \$64.91," to cover the expense for the bare factory. The buildings, two stories high and measuring 40 x 20 and 32 x 20 feet, respectively, were located on the Weston bank of the Charles River, opposite Fowle's home, from which they could be reached by a private ferry. This pleasant bucolic location was not far upstream from that originally sought by the Boston Watch Co. when that firm was looking for a spot to move to from Roxbury in 1854. The situation of the factory was described as a wild and secluded glen.²⁷

Another account²⁸ says:

The well appointed little steamer *White Vein*, owned and commanded by a Captain Gibbs, veteran of the last war, now plies regularly between Waltham and Auburndale Bridge, carrying picnic parties, etc. . . . Along the banks of the river are located the summer residences of Messrs. Cutter and Merrill, the elegant residence of R. M. Pulsiter, Mayor of Newton, the splendid mansion of Ex-Mayor Fowle, the Benyon mansion and others. . . . At sunset the river is alive with canoes, row-boats, shells and sailboats filled with ladies and gentlemen adding, with the delightful music, greatly to the natural charm of the scenery.

²⁷ M. F. Sweetser, *History of Waltham, Massachusetts*, Boston, Mass., 1889, p. 203.

²⁸ Smith, *op. cit.* footnote 22, p. 29.

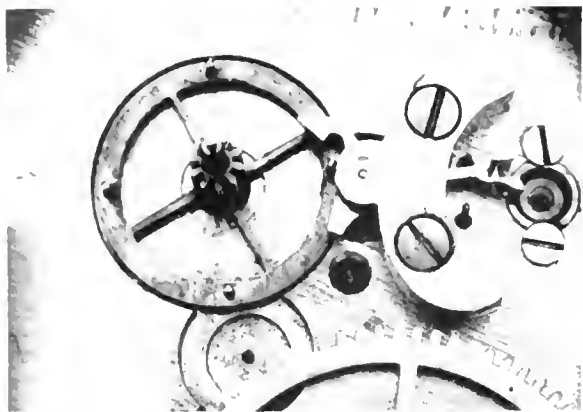


Figure 14. ESCAPE WHEEL AND PALLETS of an Auburndale timer. With four pins in the escape wheel, this particular one beats eighths of a second. (In author's collection.)

This idyllic pastoral setting surely must have been a joy to all connected with the little watch factory. It seems to typify the atmosphere of wealth and leisure into which the infant industry was brought without adequate study of the problems it would be called upon to surmount.

The Auburndale machinery came from the United States Watch Co. factory at Marion, New Jersey, which, as we have seen, was closed in 1874. William A. Wales, who was associated with Fowle in the Auburndale "adventure," had been secretary, treasurer, and director of this company. Most of the machinery came from George E. Hart and Co., of Newark, which had taken over much of the Company's equipment, eventually selling it to other factories. Warren E. Ray, a neighbor of Mr. Fowle's, commenced as manager of the factory in July 1876, and died suddenly of heart disease about October 1 of that year. He was soon succeeded by Mr. James H. Gerry, who had gone from Waltham to Newark in 1863 to superintend the building of the original machines for the United States factory.

The employees were chiefly drawn from other factories, principally the neighboring American Watch Co. at Waltham, and the defunct United States Watch Co., while some who needed no specific watchmaking skills perhaps never had worked in a watch factory before. Names, not already mentioned, that have been preserved are: George H. Bourne, L. C. Brown, Abraham Craig, Frederick H. Laves, Henry B. Fowle, Benjamin F. Gerry, William H. Guest, Jose Guinan, Sadie Hewes, Isaac Kilduff (the watchman), Justin Hinds, E. Moebus, James O'Connell (the stationary engi-

neer), Edwin H. Perry, Frank N. Robbins, John Rose, Thomas W. Shephard, William H. A. Simmons, Alfred Simpson, Thomas Steele, Oscar L. Strout, and George Wood. These, compiled from several sources,²⁹ represent only a few of the men who contributed their knowledge and skill to the enterprise; they are listed in alphabetical order because it has been found impossible to arrange them accurately according to position, magnitude of contribution, or length of service.

Of the five Hopkins patents³⁰ the first and the last are the ones covering the essential elements used in the Auburndale product. The two patents assigned in half to William D. Colt apparently were never used, nor does the device shown in figure 6 seem to have been used, although these unused patents are listed on the Auburndale movements. Now that the watch was in the hands of men accustomed to making watches, some modifications dictated by their experience and

²⁹ The sources used were Crossman, *op. cit.* (footnote 8), December 1887; Henry G. Abbot, *Watch factories of America*, Chicago, 1888, pp. 93-95; *Newton directory* for 1875, 1877, 1879, 1881, 1883, 1884-85, and 1885; *Waltham-Watertown directory* for 1877-78, 1880, 1882, 1884; and William B. Fowle, "Cash book" (see footnote 14).

³⁰ U. S. patents 161513, applied for November 13, 1873, issued March 30, 1875; 165830, applied for July 14, 1875, issued July 20, 1875; 165831, applied for June 9, 1875, issued July 20, 1875; 179019, applied for May 25, 1876, issued June 20, 1876; and 186838, applied for January 12, 1876, issued January 30, 1877. A French patent was issued to Hopkins on September 12, 1876, and a Belgian patent on September 30, 1876. For lack of records neither has been positively identified but presumably they are for the same device covered in U. S. patent 179019.



Figure 15. VERGE AND LEVER for an Auburndale timer. The one on the left beats eighths of a second; that on the right beats quarters. (In author's collection.)

by considerations of expediency in manufacture were made. The movement that issued was 18 size, rather thick, cased at the factory in a nickel case made by the Thierry Watch Case Co. of Boston, Massachusetts. In the winding and setting mechanisms, some changes in details were made with respect to those shown in figure 7. The dial is mounted by means of a rim which snaps over the edge of the movement as on a high-grade Swiss watch of the same era. The usual dial feet, if used, would have interfered with the rotation of the movement. For the same reason, of course, there is no dial indicating seconds.

Five jewels are found in most instances, two cap jewels and two hole jewels for the balance staff and a jeweled impulse pin. One of the faults of the movement is that the cap and hole jewels on the balance are not separable for cleaning. After the jewels were inserted part of the setting was spun down over them, making the assembly permanent. A few movements with only one jewel are known, the cap and hole jewels being metal "jewels" likewise set under a spun-over rim. Whether or not the impulse jewel found in these last-mentioned movements is original or a later intrusion remains undetermined. It is easy to conceive that the factory would see no more necessity for an impulse jewel than for other jewels.

The lever escapement is the only one known to have been used, but two varieties of this are found (see fig. 11). One is a standard club-tooth lever with banking pins, the other, much more interesting because unconventional, has pointed pallets and all the lift on the escape wheel, which has very short stubby teeth, very much like the wheel of a pin-pallet escapement. No banking pins are used, the banking taking place between the pallets and the wheel. An examination of a number of these watches, with serial numbers ranging from 46 to 507,³¹ reveals no correlation between the serial number and the style of escapement, from which one may conclude that the pointed pallet escapement was originally used; later four balance jewels were added and the escapement changed to the conventional club-tooth pattern. As complaints came in about the defective running of

the watch these change were apparently substituted at the factory in customers' watches. The movements with the pointed-pallet escapement seldom show much wear; on the other hand, watch no. 224,³² which has the conventional escapement and five jewels, is very much worn and must have run for many years.

These watches are stem wound by turning opposite to the usual direction and are set through the winding crown after actuating a setting lever located under the front bezel. The plates, bridges, and ring gear are nickel-plated and highly buffed, making a very showy movement, the only instances of such a finish on watches in the author's experience. In figure 12 is shown a 24-hour dial to fit the movement. Special dial gearing would be required for the hour hand to accompany this dial.



Figure 10. Dial for 10-Second Model Auburndale timer. (In author's collection)

The first of these watches were placed on the market in 1877, priced at \$10.00 to the trade. Soon complaints came in that they were defective in operation and many were returned. We have seen from the specimens examined that there seems to have been no established model produced in quantity. The dial and the number of jewels varied, as well as the escapement, suggesting that the owners were groping for a salable variant of the design for which they had tooled the factory. Probably the pointed pallet escapement was used first, it being the less expensive of the two.

³² In the author's collection.

³¹ No. 46 courtesy of the late C. A. Ilbert (this watch is now in the Science Museum, South Kensington, London); 124, 170, 224, 241 in the author's collection; 161 Abbot, *op. cit.* (footnote 29); 250 Henry Ford Museum, Dearborn, Michigan; 361 F. Earl Hackett; 387 Dr. Alfred G. Cossidente; 403 Dr. W. B. Stephens; 423 Crossman, *op. cit.* (footnote 8); and an unnumbered movement illustrated in *American Jeweler*, December 1898, vol. 17, no. 12, p. 371.

In addition to the saving effected by not requiring banking pins, the escape wheel was much cheaper to cut, as the teeth were very short and strong (see fig. 11). Since the banking took place between the pallets and the escape wheel, there was no adjustment for the amount of slide; and since the watches were not made to close tolerances, the slide was necessarily excessive and consequently power consuming. The conventional club-tooth escapement was probably substituted as less troublesome, although the banking pins were fixed and could only be adjusted by bending them. The pallets remained solid steel, without adjustable stone inserts.

At this stage of affairs approximately \$140,000 had been invested in the venture, the market was already glutted with conventional watches which enjoyed the confidence of retailers, and the Auburndale Rotary had won a bad reputation. The success of any watch depends largely on the confidence the retail dealers have in it. They are looking for a product easy to sell at an attractive profit as well as one that will stay sold and create a satisfied customer. Fowle was of course very much disappointed; before going into the venture he had been advised that he could expect to produce 200 watches per day on an expenditure of \$16,000.³³ The watches reached the market at a time, the fall of 1877, almost coincidental with application by D. Azro A. Buck for patents on what was to become the Waterbury rotary. These patents represented a new and economically sound expression of the basic ideas of Hopkins. The Waterbury associates immediately commenced work aimed at getting their watch on the market by June 1878.³⁴ News of this certainly reached Auburndale where they were not only well aware of the cost of producing their rotary but were also aware of the strict cost and performance studies which Locke and Merritt would apply to any watch before they would invest in it. Knowledge of this very able and well organized rival, coupled with the troubles experienced in manufacturing and selling the Auburndale Rotary, seem to account for the decision to abandon it. It was unfortunate that the timing of events happened just as it did for a little more work on the Auburndale and the tools for making it would probably have placed it on a firm footing in the trade, although obviously it could never compete with what eventually became the low-priced watch,

really a scaled-down alarm clock minus the alarm mechanism.

It is said that about one thousand of the "Rotaries" were made. The highest serial number to come to the author's attention, 507, may indicate that only a part of the watches started were finished.

Accounts agree³⁵ that the next product of the factory was a "Timer" containing a novel escapement patented on May 28, 1878,³⁶ by William A. Wales. Early specimens are marked "Pat. Applied For," but one with the serial number 996³⁷ bears no reference at all to a patent, presumably because issuance of the patent or patents was imminent. Apparently the timer was in full production before the patent was issued on May 28. Specimens with higher serial numbers are stamped with three patent dates, May 28, 1878,³⁸ June 24, 1879, and September 30, 1879, as seen in figure 13, which also shows the arrangement of the train. In this escapement the escape wheel (fig. 14) carries in the rim any suitable number of steel pins all on the same radius from, and parallel to, the axis of wheel rotation. In all cases the wheel makes one revolution per second. The verge (figs. 14 and 15) is so proportioned that the distance between the points of repose on the entrance and exit pallets will stop the wheel at intervals equal to half the angular distance between the pins.

In other words, with two pins in the escape wheel the escapement will beat quarters of a second, because starting from a point of repose the wheel will be arrested on the other point of repose after turning through 90°. With four pins in the escape wheel and a suitably proportioned verge the escape wheel advances in steps of 45° and beats eighths of a second. The growing trend in this period to standardize the

³³ Crossman, *op. cit.* (footnote 8), January 1888, pp. 400-401; Abbot, *op. cit.* (footnote 29).

³⁶ U. S. patent 204400.

³⁷ U. S. National Museum cat. no. 248691.

³⁸ U. S. patent 204400. The text of this patent speaks of dividing the second into "halves, quarters, eighths, etc." and in the summation of claims of "an escape wheel, &c. provided with one or more pairs of pins . . ." showing that measuring tenths of a second with a five-pin escape wheel was not conceived at this time. It is interesting to note that in referring to the drawings shown in figure 12 the text states "In the present instance two pairs of pins are used to denote quarter seconds." Only one pair of pins is shown, which is correct. This seems, however, to reflect carelessness on the part of patent attorneys and examiners, as the error exists in the original manuscript patent application preserved in the National Archives, Washington, D. C.

³⁴ Crossman, *op. cit.* (footnote 8), December 1887, p. 400.

³⁵ Crossman, *op. cit.* (footnote 8), January 1888, p. 33.

timing of sporting events in intervals of fifths of a second is reflected in still another model having five pins in the escape wheel and beating tenths of a second. By the nature of the verge in this escapement, it will be seen that the number of beats must be twice the number of pins in the escape wheel, leaving no way to secure an odd number of beats per second, hence the $\frac{1}{10}$ -second model. This must have been a less desirable form because of the much smaller verge required, plus the problem of accelerating so much mass from a dead stop 600 times per minute.

Figure 16 illustrates a dial for this $\frac{1}{10}$ -second model which the author found in a lot of unused parts left

serial numbers below 1,000; the barrel arbor is short, barely long enough to attach the winding handle; later this arbor was made longer. Patent 204274 issued to Benjamin Wornelle of Brighton, Massachusetts, on May 28, 1878, the same date as Wales' escapement patent, may have suggested this winding handle. On watches with higher serial numbers, there are two arrows on the handle to show the direction to wind.

The earliest of these timers had a slide on the side of the case to stop the movement by means of a piece of thin spring steel applied roughly tangentially to the smooth rim of the three-arm, solid steel balance wheel. When this action is reversed to start the movement, the spring, in retracting from the wheel rim, starts the wheel swinging. Soon this slide on the case was dispensed with by fitting a curved sheet-metal rack into a groove turned in the edge of the balance cock. Engaging this rack was a pinion with a square hole through which the square stem could slide to set the hands back to zero as it had from the beginning, while turning the stem now would actuate the pinion and rack to start and stop the movement, as the slide in the case had originally done.

Various minor changes, dictated by experience and the need for economy in manufacture, were made in these movements. After about the first thousand the diameter of the balance was reduced from approximately .700 to about .530 inch. This smaller wheel was, of course, much more suitable to vibrate at the faster speeds required on the models beating eighths and tenths of a second. At some time between the manufacture of watches bearing serial numbers 3135 and 3622, the formerly separate winding pawl and spring were combined into one piece that could be entirely made in a punch press. Another economy move was to stamp the name and patents in place of hand engraving. For a long time hand engraving was used, although stamping had been used from the beginning on the earlier rotary watch.

The case was very similar to that used on the rotary. The dial, of white enamel with snap rim fastened by a screw, carried three graduated circles, an outer circle graduated in seconds up to sixty surrounding two smaller subsidiary dials. The top one of these smaller dials recorded minutes elapsed up to ten and the lower one recorded fractions of a second. The

¹ U. S. patent 216112, issued to William A. Wales and assigned to William B. Fowle, was applied for on November 14, 1878, after the device was already in use on earlier specimens of these watches.



Figure 17. A TIMER DIAL that is probably either experimental or very early. Note that the fractions of a second (quarters) are shown on the outside dial instead of on a separate dial. This dial was converted at the factory for use as the base of a hairspring vibrating stand. A dial different from this but having the same arrangement of circles is known. (In author's collection.)

over when the factory closed. The watch had an 18-size $\frac{3}{4}$ -plate movement with grained nickel finish. The escapement is special, as we have seen, but the fork, roller, and balance action are conventional. There are five jewels, four to support the balance staff and an impulse jewel. The barrel arbor comes through the top plate with a square, as in a keywind watch, but is fitted with a winding handle, so that a key is unnecessary. This handle appears to be an afterthought, because on the earlier models (those with

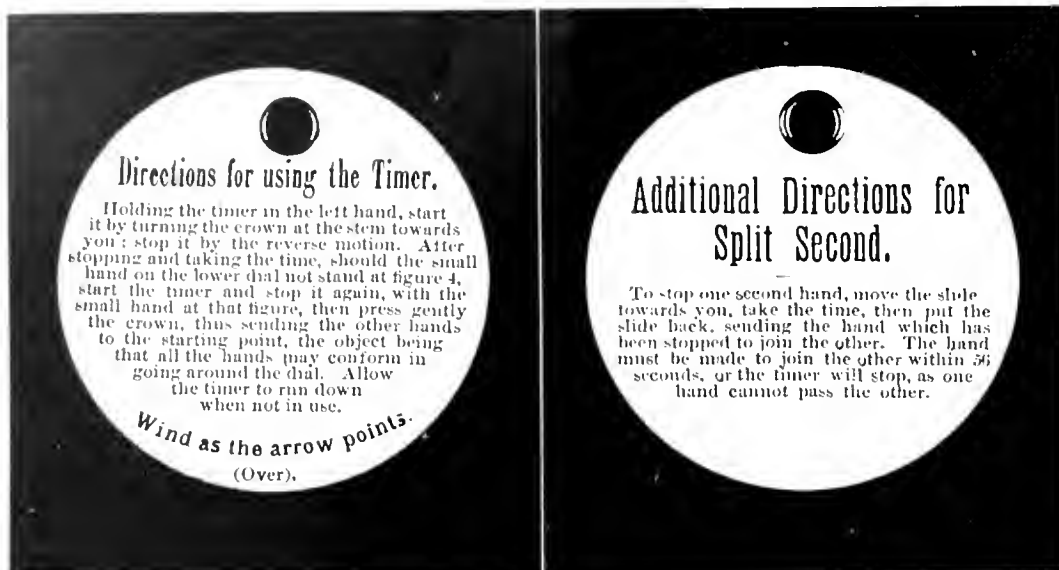


Figure 18.—TAG DISPLAYING DIRECTIONS FOR USE OF THE AUBURNDALE TIMER.
(In author's collection.)

same dial was used on movements indicating quarters and eighths of seconds, all being graduated in eighths. A dial without provision for indicating the fractions of a second on a separate small dial may be seen in figure 17. This last has been made into a stand for hair spring work and is shown with balance and spring just as it came from the Auburndale factory with balance spring and wheel for a timer still in place.

The sweep second hand and the minute register hand are attached to heart-shaped cams friction driven from their respective staffs. They are reset by a bar pivoted beneath the dial and actuated by the stem through pressure on the crown. An original instruction tag as sent from the factory with these timers is seen in figure 18.

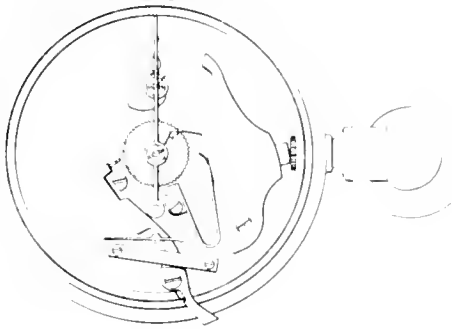
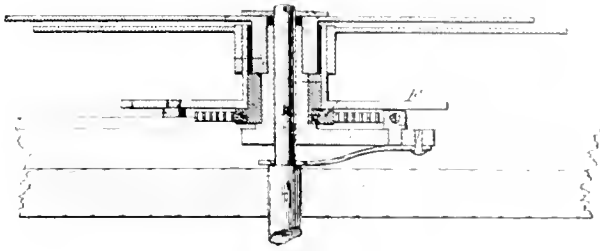
Figure 19 shows the mechanism of the split-second model as represented in U. S. patent 220195 of September 30, 1879, issued to William A. Wales and assigned to William B. Fowle.⁴⁰ A split-second mechanism is used to time the finish of two horses in the same race or any other similar event. In usual watches of this nature the watch will run along indefinitely with the extra or split second hand stopped although this hand will not record more than a difference of one minute from the main sweep hand. This was not true of the Auburndale, as pointed

⁴⁰ The mechanism was also covered by British patent 3893, issued September 27, 1879, to Philip Syng Justice on behalf of William B. Fowle.

out in the instructions. The reason for this is that motion is conveyed to this hand through a hair spring which would be damaged if allowed to overwind. To prevent this a stop is interposed which will halt the entire watch unless directions are followed. The serrated wheel *F*, of hardened steel, driving the second sweep hand, is cut on the edge with 120 serrations; stopping of this hand therefore is only to the nearest half second regardless of how minutely the escapement is dividing time. This is rather a serious defect as, if timing a horse race as an example, the time of the fastest horse is taken on this hand which registers a lesser degree of accuracy than the time recorded on the second and less important horse. A general view of one of these watches is seen in figure 20.

Success and Failure

It would be pleasant to report that after the fiasco of the rotary model these timers were a financial success, but the facts indicate otherwise. They were well built and reliable, so that the trade was pleased to stock and promote them. The public responded well when in the market for a timer, as might be expected, since no other stop watch with fractional second dial or split-second hand was made in the country. Those imported from abroad were many times as expensive. Unfortunately the demand was seasonal. Sometimes, during the racing season,



demand would reach 400 per month, while at other seasons of the year practically none at all were sold. Some remained in stock during the remaining life of the company, as is shown by the following advertisement,⁴⁰ which was accompanied by an illustration of the watch:

The old reliable Auburndale Chronograph Timers, for sale by Edward H. Brown, No. 16 Maiden Lane, New York. The manufacture of these watches having been discontinued for reasons entirely apart from their value and reliability, the stock in existence is very limited, and is now in the hands of Mr. Edward H. Brown, No. 16 Maiden Lane, New York City, the well known and reliable dealer in Watches, Diamonds and Jewelry. The Auburndale timer has been in the hands of a number of competent judges, and has always been found to be accurate. It is of convenient size, and is contained in a German silver case, nickel plated. The timers are manufactured in two qualities, without split seconds for \$15 and with the split second for \$25. They all have minute, second and lightning hands. We recommend all desiring a cheap and reliable timer to apply at once to Mr. Brown, No. 16 Maiden Lane, New York.

A steadier market was sought with the introduction of a low priced $\frac{3}{4}$ -plate, back-setting, 18-size watch to compete, it was hoped, with the full-plate watches of similar price made by the established companies. Nearly all these watches had seven jewels, some few had more. The majority were key wind and set with

Figure 19. SPLIT SECOND MECHANISM of the Auburndale timer, as shown in drawings from U. S. patent 220197, issued September 30, 1876.

a folding winding key permanently attached to the barrel arbor, as in figure 21. These were named "Lincoln" for Mr. Fowle's son, Lincoln A. Fowle,⁴¹ and had a solid steel balance with screws and the general appearance of a compensated balance. A stem-wound, lever-set edition of the same basic watch was named "Bentley" for Bentley D. Fowle, another son.⁴² This had a cut bimetallic balance and higher finish. Conventional gilt finish was used on both of these models, although one isolated specimen found in factory remainders⁴³ has a bright nickel finish comparable with the rotary watch. These watches were designed by Chauncey Hartwell,⁴⁴ after J. H. Gerry had removed to Lancaster, where the Lancaster Watch Co., organized in August 1877, was attempting to bring a line of watches onto the market although beset by acute financial woes similar to those building up at Auburndale. To return to our $\frac{3}{4}$ -plate watches, it may be said that they were well made for the price, reliable, and successful from a manufacturing point of view but could not be sold at a figure high enough to return a profit on the manufacture.

Up to this time, about November 1, 1879, the Auburndale Watch Co., had existed as a private company; now it was incorporated with a book value of \$500,000, and William B. Fowle, who at this point had invested about \$250,000 (mostly unrecoverable) in the enterprise, was elected president, and George H. Bourne was elected secretary and treasurer.

After a quantity of these Lincoln and Bentley watches had been manufactured⁴⁵ and it had become clear that they could not be attractively priced to the trade, the company sought a product adapted to their factory equipment for which a constant market could be found. The product chosen was a line of metallic thermometers,⁴⁶ Two patents, 240058 and 240059,

⁴⁰ *Watchmaking*, 1884-85, Crossman, *op. cit.*, footnote 8, December 1887.

⁴¹ Records of Veterans Administration pension application WF 666 675 of Mary F. Fowle (widow of William B. Fowle).

⁴² Serial 926, in author's collection.

⁴³ *Watchmaking*, 1879.

⁴⁴ Each model of watch made at Auburndale was numbered in its own series, starting at number 1, contrary to the usual watch factory practice where blocks of serial numbers are assigned to different models. Other Auburndale products seem not to have borne serial numbers.

⁴⁵ Crossman, *op. cit.*, footnote 8, December 1887.

⁴⁶ *The Jeweler's Circular and Horological Review*, July 1884.

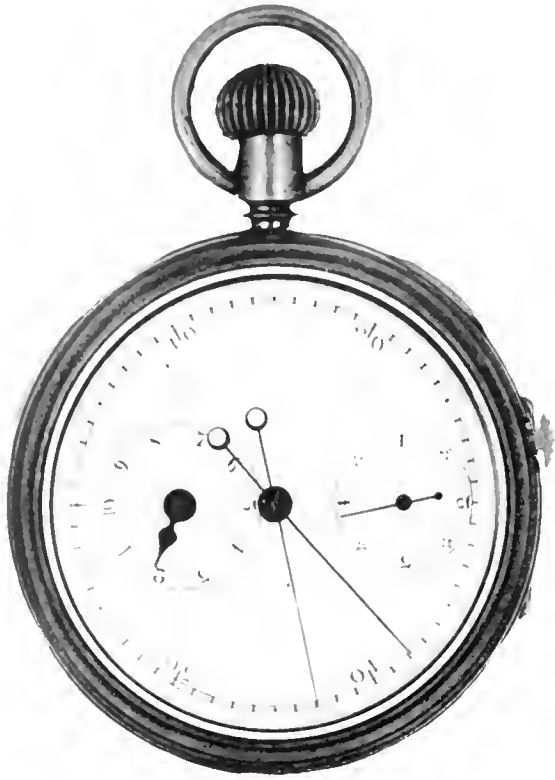


Figure 20 (left).—AUBURNDALE TIMER WITH SPLIT SECOND HAND. Note the stop and start lever for the "split" hand at the side of the case. (In author's collection.)

Figure 21 (above).—AUBURNDALE THREE-QUARTER PLATE WATCH, typical of both Lincoln and Benley grades. (In author's collection.)

were issued to William A. Wales, assignor to the Auburndale Watch Co., of Weston, Massachusetts, on April 12, 1881. Whether these patents represent the first thermometers made at Auburndale or reflect the result of experience gained in making conventional models is not clear. The earliest evidence dating the appearance of the thermometer is the 1881 *Boston directory* which appeared on July 1. This illustrates the same model of thermometer seen in figure 22. The patents cover means of eliminating springs of any sort from the mechanism, so that the hand or dial pointer is entirely under the influence of the fused bimetallic thermal strips. Manufacture of the timers was carried along with thermometer manufacture at first, but production of the timer was finally dropped, as the stock on hand was constantly increasing, and for a while the factory was at last operated at a profit, on thermometers alone. These were furnished in cases from 20 inches in diameter down to the size of a ten cent piece, according to the advertising.

Unfortunately Mr. Fowle had suffered so much loss through the watch venture and from other investments that he was forced to make an assignment of his personal estate. The watch company, without his

support, was carrying too large a burden of debt to be self-supporting. In the fall of 1883 a voluntary assignment was made and the equipment was sold in February 1884.⁴⁸ The *Newton directory* of 1885 lists W. B. Fowle as a thermometer manufacturer on Woodbine Street, "house near." His home, "Tanglewood," was on Woodbine Street and perhaps the thermometer business was operating in one of the outbuildings. William A. Wales assigned to the Auburndale Watch Co. patent 276101, of December 4, 1883, covering details of a unit counter for keeping score in games, and for similar work. Among the relics in the author's collection is a box bearing the label "Auburndale Counter, W. B. Fowle & Son, Auburndale, Mass." These counters were packed two in a box, the box just mentioned being suitable to contain counters the size of the thermometer in figure 22. Figure 23 shows a larger counter measuring 4½ inches in diameter. From this and the fact that Fowle as late as 1887, is carried in the *Newton directory* as a manufacturer of metallic thermometers, it seems that some attempt was made after dissolution of the watch company to carry on manufacturing,

⁴⁸ *Ibid.*

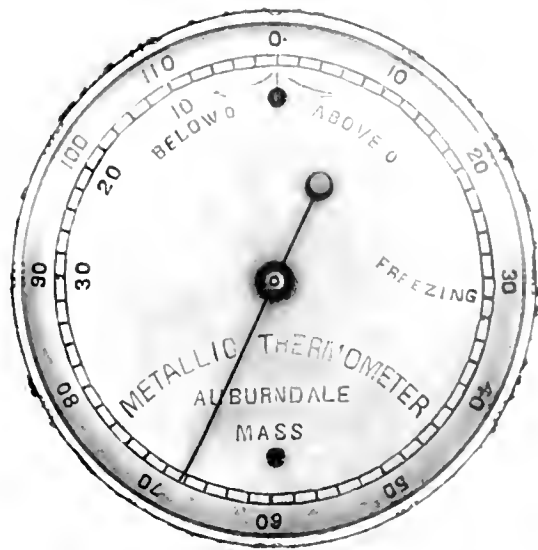
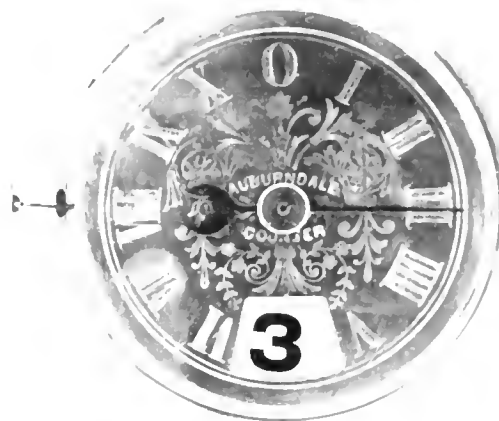


Figure 22 (*above*). AUBURNDALE THERMOMETER, about 1 3/4 inches in diameter. (In author's collection.)

Figure 23 (*right*). AUBURNDALE COUNTER. Pressure on the projecting stem indexes the inner dial, showing through the window, at the same time ringing a bell. This dial is numbered from zero through six. The outside hand is held in place by friction and is manually set as desired. There is no connection with the inner mechanism.



or perhaps only the assembly on a small scale of parts previously manufactured. The *Directory* of 1889 lists Fowle as an accountant on Ash Street, Auburndale. He had bought this property in 1887, presumably after disposing of "Tanglewood" which now would be too large for his needs. In the editions of 1891 and 1893 he is listed as United States collector of internal revenue, with an office at the Post Office building, Boston. In 1895 he appears as an accountant at the same address and from then to his death in 1902 he is listed as an accountant at his home address in Auburndale.

Jason R. Hopkins, inventor of the first Auburndale product, passed away in Washington late the same year, 1902, having spent all the intervening years as a watchmaker.

The Lesson

The life of a pioneer has always been arduous. The story we have just reviewed illustrates this. Hopkins was a successful workman with clever and novel ideas. Fowle had been very successful in an entirely

unrelated field. Wales had been very successful in importing and selling watches but the watch factory which he had owned in part had failed, the fault more probably that of the times than of the man. The various superintendents and foremen were first-class men with ample background in making conventional watches. At the time no one could have had experience in manufacturing exactly the grade and type of watch being attempted, for this was the pioneer effort.

The country was in the grip of a long, lingering depression following the Civil War. Money was tight. The Auburndale Rotary was conceived as a very low priced watch which would at the same time include the desirable and unusual feature of close timekeeping. Could these ideals have been adhered to, there is little reason to question that it would have found a market, even in hard times.

We have seen that every effort to improve the original watch added to its cost, and here lies the real reason why it failed to win acceptance. By the time it reached the market it was no longer priced below conventional watches and at least some specimens were not reliable in performance. To make matters even worse, the best features of Hopkins' rotary watch had been incorporated by Focke and Merritt into a competing rotary watch much better engineered for cheap mass production.

At this point the only hope for the factory seemed to be the manufacture of some other watch or similar small mechanism. The Auburndale timer, with the exception perhaps of the split-second model, was a triumph mechanically and it returned a profit, but not enough to meet the financial needs of its sponsors. Much the same may be said of all the later Auburndale products.

The rotary had been of doubtful value when Fowle bought it, and the new organization was not able to contribute the necessary manufacturing engineering to make it a successful product. By the time this necessity was recognized, debts had mounted to the point where later products, which might have been successful on their own, were not able to carry the burden. The whole affair can be viewed as a very expensive educational adventure from which the students were not able to salvage enough to put their education to any use.

Surely they received a clear illustration of how dangerous it can be to engage in an enterprise without sufficient background or a long and careful study of design, manufacturing processes, costs, and market and sales analysis. For although numerous fortunes have been made in watch manufacturing, many more have been lost, and often those who put every effort at their command into such ventures came away with only sad experience as their reward. Thus ended the story of the Auburndale Watch Company.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 5

DEVELOPMENT OF THE PHONOGRAPH AT
ALEXANDER GRAHAM BELL'S VOLTA LABORATORY

Leslie J. Neville

DEVELOPMENT OF THE PHONOGRAPH AT ALEXANDER GRAHAM BELL'S VOLTA LABORATORY

By Leslie J. Newville

The fame of Thomas A. Edison rests most securely on his genius for making practical application of the ideas of others. However, it was Alexander Graham Bell, long a Smithsonian Regent and friend of its third Secretary S. P. Langley, who, with his Volta Laboratory associates made practical the phonograph, which has been called Edison's most original invention.

THE AUTHOR: Leslie J. Newville wrote this paper while he was attached to the office of the curator of Science and Technology in the Smithsonian Institution's United States National Museum.

THE STORY OF Alexander Graham Bell's invention of the telephone has been told and retold. How he became involved in the difficult task of making practical phonograph records, and succeeded (in association with Charles Sumner Tainter and Chichester Bell), is not so well known.

But material collected through the years by the U. S. National Museum of the Smithsonian Institution now makes clear how Bell and two associates took Edison's tinfoil machine and made it reproduce sound from wax instead of tinfoil. They began their work in Washington, D. C., in 1879, and continued until granted basic patents in 1886 for recording in wax.

Preserved at the Smithsonian are some 20 pieces of experimental apparatus, including a number of complete machines. Their first experimental machine was sealed in a box and deposited in the Smithsonian archives in 1881. The others were delivered by Alexander Graham Bell to the National Museum in two lots in 1915 and 1922. Bell was an old man by this time, busy with his aeronautical experiments in Nova Scotia.

It was not until 1947, however, that the Museum

received the key to the experimental "Graphophones," as they were called to differentiate them from the Edison machine. In that year Mrs. Laura F. Tainter donated to the Museum 10 bound notebooks, along with Tainter's unpublished autobiography.¹ This material describes in detail the strange machines and even stranger experiments which led in 1886 to a greatly improved phonograph.

Thomas A. Edison had invented the phonograph in 1877. But the fame bestowed on Edison for this startling invention (sometimes called his most original) was not due to its efficiency. Recording with the tinfoil phonograph is too difficult to be practical. The tinfoil tears easily, and even when the stylus is properly adjusted, the reproduction is distorted and squeaky, and good for only a few playbacks. Nevertheless young Edison, the "wizard" as he was called, had hit upon a secret of which men had dreamed for

¹ Charles Sumner Tainter (1854-1940), "The talking machine and some little known facts in connection with its early development," unpublished manuscript in the collections of the U. S. National Museum.



Figure 1. CHARLES SUMNER TAINTER (1851–1910) from a photograph taken in San Diego, California, 1919. (*Smithsonian photo* 42729 .A.)

centuries.² Immediately after this discovery, however, he did not improve it, allegedly because of an agreement to spend the next five years developing the New York City electric light and power system.

Meanwhile Bell, always a scientist and experimenter at heart, after his invention of the telephone in 1876 was looking for new worlds to conquer. If we accept Tainter's version of the story, it was through Gardiner Green Hubbard that Bell took up the phonograph

² One of the most interesting prophecies was written in 1656 by Cyrano de Bergerac, in his *Comic history of the states and empires of the Moon*:

"I began to study closely my books and their covers which impressed me for their richness. One was decorated with a single diamond, more brilliant by far than ours. The second seemed but a single pearl cleft in twain.

"When I opened the covers, I found inside something made of metal, not unlike our clocks, full of mysterious little springs and almost invisible mechanisms. 'Tis a book, 'tis true, but a miraculous book, which has no pages or letters. Indeed, 'tis a book which to enjoy the eyes are useless; only ears suffice. When a man desires to read, then, he surrounds this contrivance with many small tendons of every kind, then he places the needle on the chapter to be heard and, at the same time, there come, as from the mouth of a man or from an instrument of music, all those clear and separate sounds which make up the Lunarians' tongue.'" (See A. Cocurov and G. Clarence, *Le phonographe*, Paris, 1929, p. 9, 10.)

challenge. Bell had married Hubbard's daughter Mabel in 1879. Hubbard was then president of the Edison Speaking Phonograph Co., and his organization, which had purchased the Edison patent, was having trouble with its finances because people did not like to buy a machine which seldom worked well and proved difficult for an unskilled person to operate.

In 1879 Hubbard got Bell interested in improving the machine, and it was agreed that a laboratory should be set up in Washington. Experiments were also to be conducted on the transmission of sound by light, and this resulted in the selenium-cell Photophone, patented in 1881. Both the Hubbards and the Bells decided to move to the Capital. While Bell took his bride to Europe for an extended honeymoon, his associate Charles Sumner Tainter, a young instrument maker, was sent on to Washington from Cambridge, Massachusetts, to start the laboratory.³ Bell's

³ Tainter retained a lifelong admiration for Alexander Graham Bell. This is Tainter's description of their first meeting in Cambridge: "... one day I received a visit from a very distinguished looking gentleman with jet black hair and beard, who announced himself as Mr. A. Graham Bell. His charm of manner and conversation attracted me greatly. ..." Tainter, *ib. id.*, footnote 1, p. 2.

cousin, Clichester Bell, who had been teaching college chemistry in London, agreed to come as the third associate. During his stay in Europe Bell received the 50,000-franc (\$10,000) Volta prize, and it was with this money that the Washington project, the Volta Laboratory Association,⁴ was financed.

Tainter's story, in his autobiography, of the establishment of the laboratory, shows its comparative simplicity:

Figure 2. PHOTOGRAPHING SOUND IN 1884. A rare photograph taken at Volta Laboratory, Washington, D. C., by J. Harris Rogers, a friend of Bell and Tainter (*Smithsonian photo* 44312-E).

A description of the procedure used is found on page 67, of Tainter's unpublished autobiography (see footnote 1). There, Tainter quotes Clichester Bell as follows:

"A jet of bichromate of potash solution, vibrated by the voice, was directed against a glass plate immediately in front of a slit, on which light was concentrated by means of a lens. The jet was so arranged that the light on its way to the slit had to pass through the nappe and as the thickness of this was constantly changing, the illumination of the slit was also varied. By means of a lens . . . an image of this slit was thrown upon a rotating gelatine-bromide plate, on which accordingly a record of the voice vibrations was obtained."

I therefore wound up my business affairs in Cambridge, packed up all of my tools and machines, and . . . went to Washington, and after much search, rented a vacant house on L Street, between 13th and 14th Streets, and fitted it up for our purpose.⁵ . . . The Smithsonian Institution sent us over a mail sack of scientific books from the library of the Institution, to consult, and primed with all we could learn . . . we went to work.⁶ . . . We were like the explorers in an entirely unknown land, where one has to select the path that seems to be most likely to get you to your destination, with no knowledge of what is ahead.

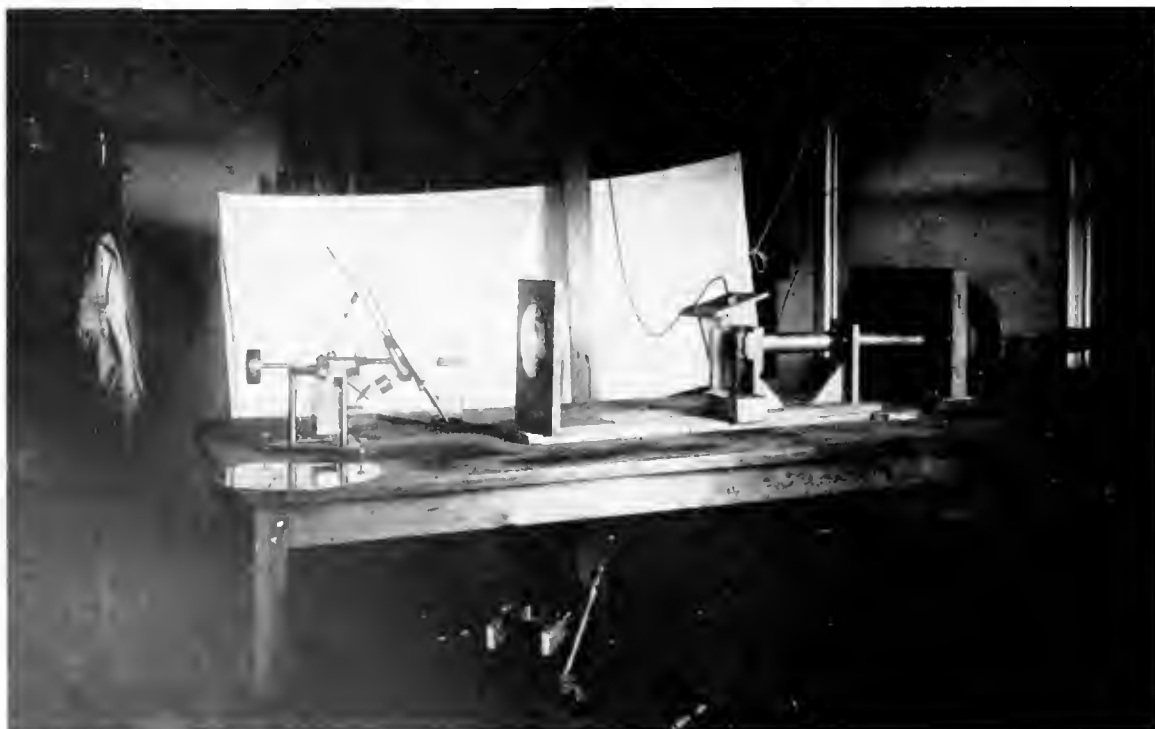
In conducting our work we had first to design an experimental apparatus, then hunt about, often in Philadelphia and New York, for the materials with which to construct it, which were usually hard to find, and finally build the models we needed, ourselves.⁷

⁴ A. G. Bell apparently spent little time in the Volta Laboratory. The Dr. Bell referred to in Tainter's notebooks is Clichester A. Bell. The basic graphophone patent (U. S. patent 341214) was issued to C. A. Bell and Tainter. The Tainter material reveals A. G. Bell as the man who suggested the basic lines of research (and furnished the money), and then allowed his associates to get the credit for many of the inventions that resulted.

⁵ Tainter, *op. cit.* (footnote 1), p. 3

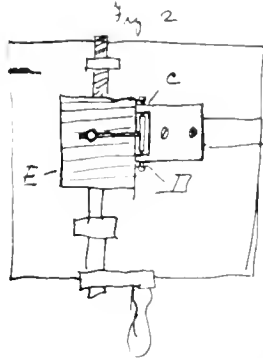
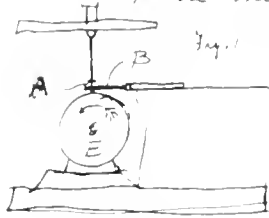
⁶ *Ibid.*, p. 5.

⁷ *Ibid.*, p. 30.



Saturday May 9-1883.

Made the following experiment - today.



The cylinder of the Edison phonograph was covered with a coating of paraffin-wax and then turned off true and smooth.

A cutting style A , secured to the end of a lever B was then adjusted over the cylinder as shown. Lever B was pivoted at the points $C-D$, and the only pressure exerted to force the style into the wax was due to the weight of the parts.

Upon the top of A was fixed a small brass disk, and immediately over it a sensitive water-jet adjusted so that the stream of water at its sensitive part fell upon the center of the brass disk.

The phonograph cylinder E was rotated while words and sounds were shouted to the support to which the water jet was attached, and a record that was quite visible to the unaided eye was the result.

Noted by ~~Ed~~, May 19-1883.

FIGURE 3.—PAGE FROM NOTE-BOOK of Charles Sumner Tainter, describing an experiment in sound recording. The Tainter notebooks, preserved in the U.S. National Museum, describe experiments at the Volta Laboratory, in the 1880's. The Graphophone patents of 1886, were the result of this research. (Smithsonian photo 44312.)

The experimental machines built at the Volta Laboratory include both disc and cylinder types, and an interesting "tape" recorder. The records used with the machines and now in the collections of the U. S. National Museum, are believed to be the oldest reproducible records preserved anywhere in the world. While some are scratched and cracked, others are still in good condition.

By 1881 the Volta associates had succeeded in improving an Edison tinfoil machine to some extent. Wax was put in the grooves of the heavy iron cylinder, and no tinfoil was used. Rather than apply for a patent at that time, however, they deposited the machine in a sealed box at the Smithsonian, and specified that it was not to be opened without the

consent of two of the three men. In 1937 Tainter (fig. 1) was the only one still living, so the box was opened with his permission.

For the occasion, the heirs of Alexander Graham Bell gathered in Washington, but Tainter was too old and too ill to come from San Diego.

The sound vibrations had been indented in the wax which had been applied to the Edison phonograph. The following is the text of the recording: "There are more things in heaven and earth, Horatio, than are dreamed of in your philosophy. I am a graphophone and my mother was a phonograph." Remarked Mrs. Gilbert Grosvenor, Bell's daughter,

¹ As quoted by *The New York Herald*, October 28, 1937.

C. A. BELL & S. TAINTER.

RECORDING AND REPRODUCING SPEECH AND OTHER SOUNDS.

No. 341,214.

Patented May 4, 1886.

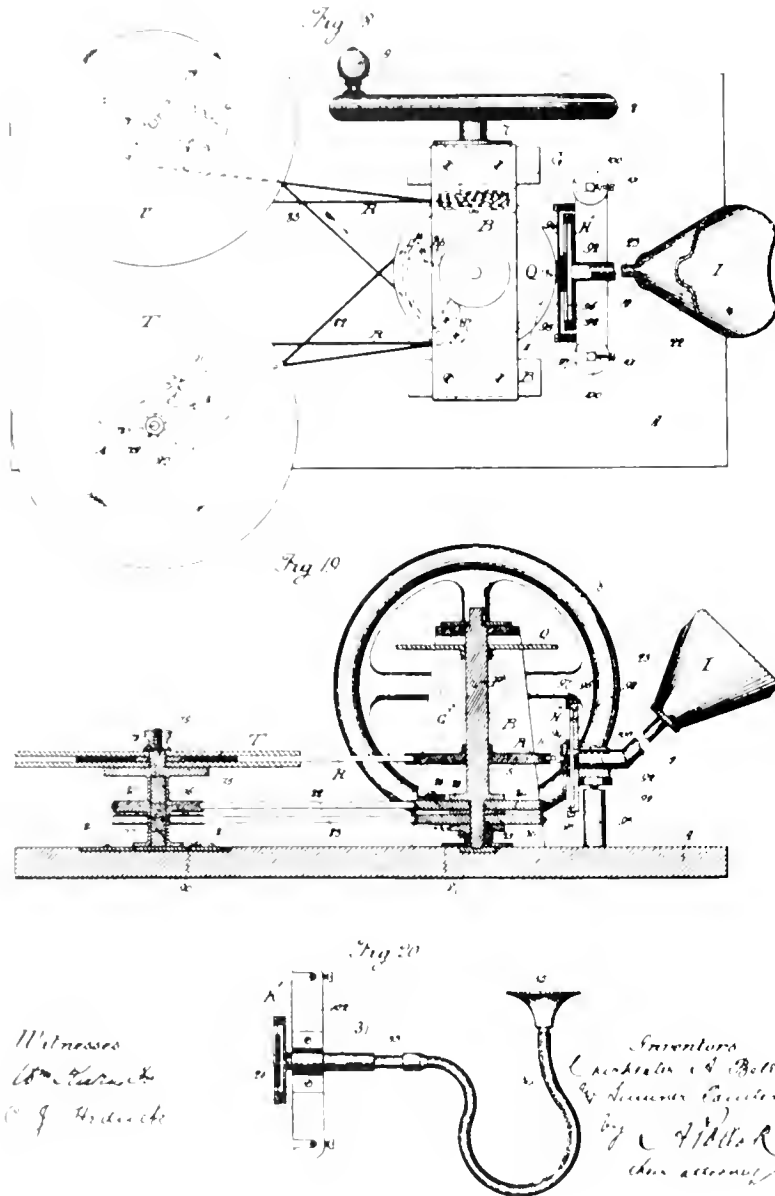


Figure 4. PATENT DRAWINGS from U. S. patent 341214, granted May 4, 1886, to Chichester Bell and C. S. Tainter.

when the box was opened in 1937, "That is just the sort of thing father would have said. He was always quoting from the classics."

The method of reproduction used on the machine, however, is even more interesting than the quotation. Rather than a stylus and diaphragm, a jet of air under high pressure was used.

"This evening about 7 P. M.," Tainter noted on July 7, 1881, "The apparatus being ready the valve upon the top of the air cylinder was opened slightly until a pressure of about 100 lbs. was indicated by the gage. The phonograph cylinder was then rotated, and the sounds produced by the escaping air could be heard, and the words understood a distance of at



Figure 5.—EXPERIMENTAL GRAPHOPHONE photographed in 1884 at the Volta Laboratory. This is similar to one preserved at the Smithsonian Institution. (*Smithsonian photo 44312 D.*)

least 8 feet from the phonograph." The point of the jet is glass, and could be directed at a single groove.

The other experimental Graphophones indicate an amazing range of experimentation. While the method of cutting a record on wax was the one later exploited commercially, everything else seems to have been tried at least once.

The following was noted on Wednesday, March 20, 1881: "A fountain pen is attached to a diaphragm so as to be vibrated in a plane parallel to the axis of a cylinder—The ink used in this pen to contain iron in a finely divided state, and the pen caused to trace a spiral line around the cylinder as it turned. The cylinder to be covered with a sheet of paper upon which the record is made. . . . This ink . . . can be rendered magnetic by means of a permanent magnet. The sounds were to be reproduced by simply substituting a magnet for the fountain pen. . . ."

The result of these ideas for magnetic reproduction resulted in patent 341287, granted on May 4, 1886; it deals solely with "the reproduction, through the action of magnetism, of sounds by means of records in solid substances."

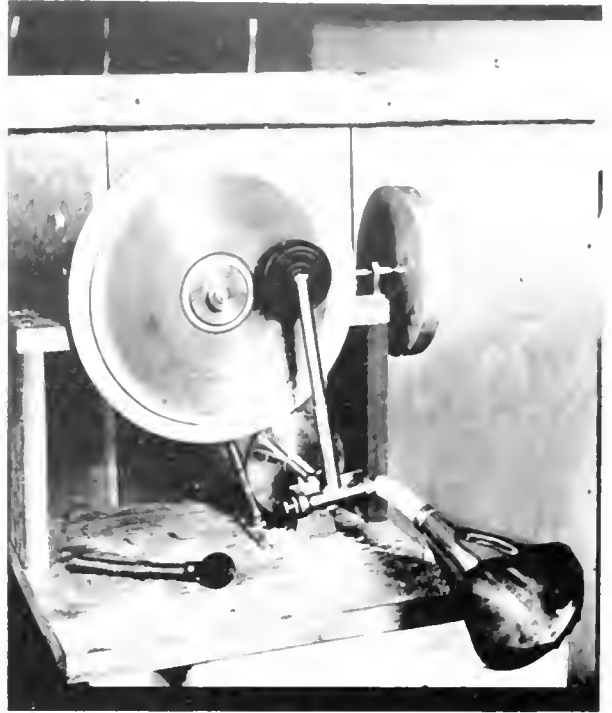


Figure 6. ANOTHER EXPERIMENTAL GRAPHOPHONE, photographed at the Volta Laboratory in 1884. (*Smithsonian photo 44312 E.*)

The air jet used in reproducing has already been described. Other jets, of molten metal, wax, and water, were also tried. On Saturday, May 19, 1883, Tainter wrote (see fig. 3):

Made the following experiment today:

The cylinder of the Edison phonograph was covered with the coating of paraffine-wax and then turned off true and smooth.

A cutting style A, secured to the end of a lever B was then adjusted over the cylinder, as shown. Lever B was pivoted at the points C, D, and the only pressure exerted to force the style into the wax was due to the weight of the parts.

Upon the top of A was fixed a small brass disk, and immediately over it a sensitive water jet adjusted, so that the stream of water at its sensitive part fell upon the center of the brass disk.

The Phonograph cylinder E, was rotated while words and sounds were shouted to the support to which the water jet was attached, and a record that was quite visible to the unaided eye was the result.

The tape recorder, an unusual instrument which recorded mechanically on a $\frac{1}{16}$ -inch strip of wax-covered paper, is one of the machines described and illustrated in U. S. patent 341214, dated May 3, 1886 (see fig. 4). The strip was coated by dipping it in a



Figure 7. ORIGINAL PLANS FOR A DISC GRAPHOPHONE PATENTED BY SUMNER LAMIER IN 1888, U. S. PATENT 285336.

solution of beeswax and paraffine (one part white beeswax, two parts paraffine, by weight), then scraping one side clean and allowing the other side to harden.

The machine of sturdy wood and metal construction, is hand powered by means of a knob fastened to the fly wheel. From the fly-wheel shaft power is transferred by a small friction wheel to a vertical shaft. At the bottom of this shaft a V-pulley transfers motion by belts to corresponding V-pulleys beneath the horizontal reels.

The wax strip passes from one 8-inch reel around the periphery of a pulley (with guide flanges) mounted above the V-pulleys on the main vertical shaft, where it comes in contact with the recording or reproducing cylinder. It is then taken up on the other reel.

The sharp recording stylus, actuated by a vibrating mica diaphragm, cuts the wax from the strip. In reproducing, a dull, loosely mounted stylus, attached to

a rubber diaphragm, carries sounds through an ear tube to the listener.

Both recording and reproducing heads, mounted alternately on the same two posts, could be adjusted vertically so that several records could be cut on the same $\frac{3}{16}$ -inch strip.

While this machine was never developed commercially, it is an interesting ancestor of the modern tape recorder, which it resembles somewhat in design. How practical it was or just why it was built we do not know. The tape is now brittle, the heavy paper reels warped, and the reproducing head missing. Otherwise, with some reconditioning, it could be put into working condition.

Most of the disc machines designed by the Volta associates had the disc mounted vertically (see figs. 5 and 6). The explanation is that in the early experiments, the turntable, with disc, was mounted on the shop lathe, along with the recording and reproducing

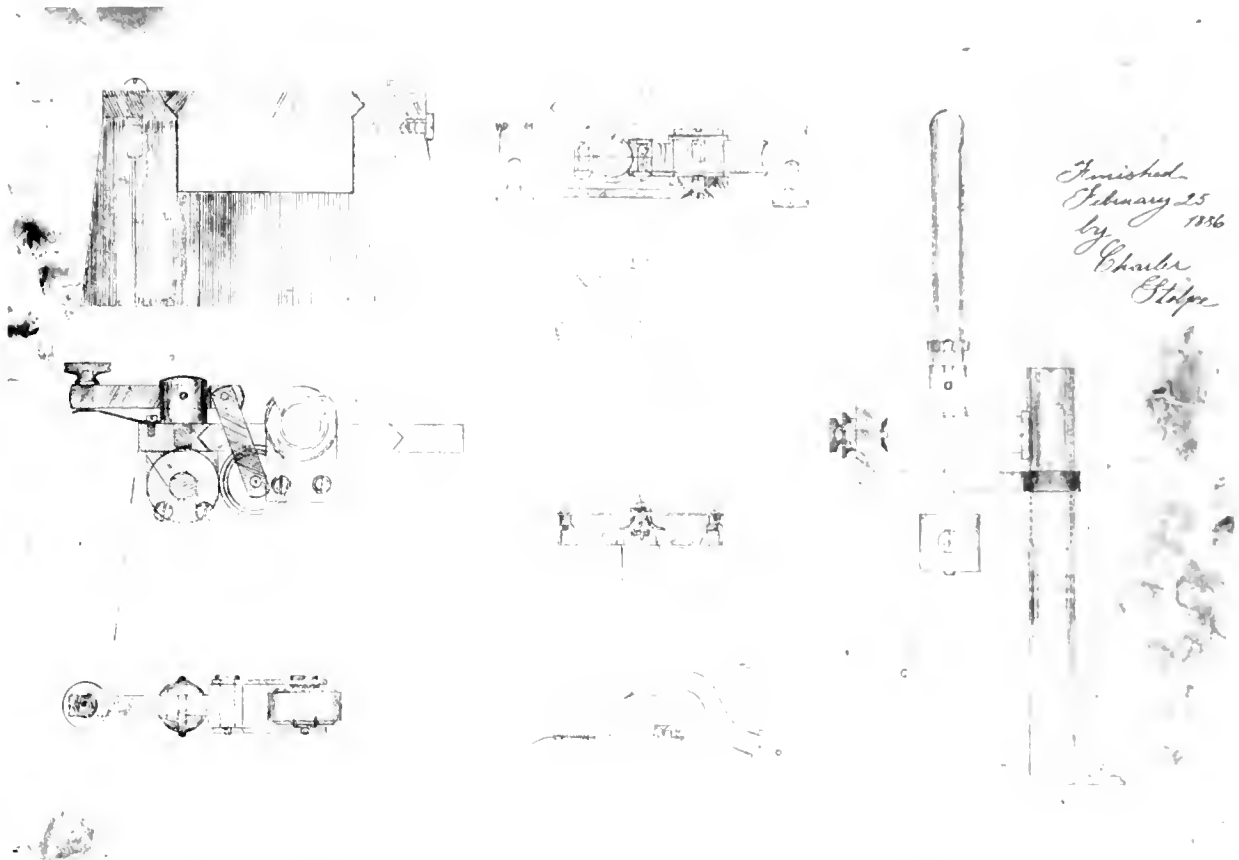


Figure 8. ANOTHER PAGE OF THE PLANS SHOWN IN FIGURE 7. The experimental Graphophone built from these plans is in the U. S. National Museum (A. O. 237665).

heads. Later, when the complete models were built, most of them featured vertical turntables.

An interesting exception has a horizontal 7-inch turntable (see figs. 7 and 8). This machine, although made in 1886, is a duplicate of one made earlier but taken to Europe by Chichester Bell. Tainter was granted U. S. patent 385886 for it on July 10, 1888.

The playing arm is rigid, except for a pivoted vertical motion of 90 degrees to allow removal of the record or a return to starting position. While recording or playing, the record not only rotated, but moved laterally under the stylus, which thus described a spiral, recording 150 grooves to the inch.

The Bell and Tainter records, preserved at the Smithsonian, are both of the lateral cut and "hill-and-dale" types. Edison for many years used the "hill-and-dale" method with both cylinder and disc records, and Emile Berliner is credited with the invention of the lateral cut Gramophone record in 1887. The

Volta associates, however, had been experimenting with both types, as early as 1881, as is shown by the following quotation from Tainter:

The record on the electro-type in the Smith's solar package is of the other form, where the vibrations are impressed *per se* to the surface of the recording material, as was done in the old Scott Phonautograph of 1857. It is cutting a groove of uniform depth, but of wavy character, having the *top* of the groove act upon the tracing part of the stylus, as is the case in the vertical type. This record we named the *zig-zag* form, and related to it were the *four* notes. Its superior advantage consisted in the projecting needle. It is a real improvement over the *zig-zag* of the Volta's Home Notes. March 26, 1881, and 1881, by the use of many carbon copies, before the stylus was sufficiently genuine and of the material of the wax, and the use of wax on the surface of the record, and a vertical cut of the groove, and the use of the

Edison, *Edison Papers*, Vol. 1, p. 28.

1888, when the Volta associates were sure that they had a number of practical inventions, they filed applications for patents. They also began to look around for investors. After giving several demonstrations in Washington, they gained the necessary support, and the American Graphophone Co. was organized to manufacture and sell the machines. The Volta Graphophone Co. was formed to control the patents.

The Howe sewing machine factory at Bridgeport, Connecticut, became the American Graphophone plant; Tainter went there to supervise the manufacturing, and continued his inventive work for many years. This Bridgeport plant is still in use today by a successor firm, the Dictaphone Corporation.

The work of the Volta associates laid the foundation for the successful use of the dictating machine in business, for their wax recording process was practical and their machines sturdy. But it was to take several more years and the renewed work of Edison and further developments by Berliner and many others, before the talking machine industry really got under

way and became a major factor in home entertainment.¹⁰

¹⁰ The basic distinction between the first Edison patent, and the Bell and Tainter patent of 1886, was the method of recording. Edison's method was to *indent* the sound waves on a piece of tin-foil (wax was included as a recording material in his English patent: the Bell and Tainter improvement called for *cutting* or "engraving" the sound waves into a wax record, with a sharp recording stylus.

The strength of Bell and Tainter patent is indicated by the following excerpt from a letter written by a Washington patent attorney, S. E. Cameron, who was a member of the law firm which carried on litigation for the American Graphophone Co. The letter is dated December 8, 1914, and is addressed to George C. Maynard, Curator of Mechanical Technology, U. S. National Museum: "Subsequent to the issuance of the Bell and Tainter patent No. 341214, Edison announced that he would shortly produce his 'new phonograph' which, when it appeared, was in fact nothing but the Bell and Tainter record set forth in their patent 341214, being a record cut or engraved in wax or wax-like material, although Edison always insisted on calling this record an 'indented' record, doubtless because his original tin-foil record was an 'indented' record. Edison was compelled to acknowledge that his 'new phonograph' was an infringement of the Bell and Tainter patent 341214, and took out a license under the Bell and Tainter patent and made his records under that patent as the result of that license."

PATENTS WHICH RESULTED FROM THE VOLTA LABORATORY ASSOCIATION

<i>Patent Number</i>	<i>Year</i>	<i>Patent</i>	<i>Inventors</i>	<i>Patent Number</i>	<i>Year</i>	<i>Patent</i>	<i>Inventors</i>
229495	1880	Telephone call register	C. S. Tainter	341287	1886	Recording and reproducing sounds	C. S. Tainter
235496	1880	Photophone transmitter	A. G. Bell, C. S. Tainter	341288	1886	Apparatus for recording and reproducing sounds	C. S. Tainter
235497	1880	Selenium cells	A. G. Bell, C. S. Tainter	374133	1887	Paper cylinder for graphophonic records	C. S. Tainter
235500	1880	Selenium cells	C. S. Tainter	375579	1887	Apparatus for recording and reproducing speech and other sounds	C. S. Tainter
241900	1881	Photophonic receiver	A. G. Bell, C. S. Tainter	380535	1888	Graphophone	C. S. Tainter
243957	1881	Telephone transmitter	C. S. Tainter	385886	1888	Graphophone	C. S. Tainter
280725	1883	Electric conductor	C. S. Tainter	385887	1888	Graphophonic tablet	C. S. Tainter
330681	1886	Transmitter for electric telephone lines	C. A. Bell	388462	1888	Machine for making paper tubes	C. S. Tainter
330682	1886	Jet microphone for transmitting sounds by means of jets	C. A. Bell	392763	1888	Mounting for diaphragms for acoustical instruments	C. S. Tainter
330683	1886	Telephone transmitter	C. A. Bell	393100	1888	Tablet for use in graphophones	C. S. Tainter
336173	1886	Telephone transmitter	C. S. Tainter	393191	1888	Support for graphophonic tablets	C. S. Tainter
341212	1886	Reproducing sounds from phonograph records	A. G. Bell, C. S. Tainter	410060	1889	Speed regulator	C. S. Tainter
341213	1886	Reproducing and recording sounds by radiant energy	A. G. Bell, C. S. Tainter	421450	1890	Graphophone tablet	C. S. Tainter
341214	1886	Recording and reproducing speech and other sounds	C. A. Bell, C. S. Tainter				

<i>Patent Number</i>	<i>Year</i>	<i>Patent</i>	<i>Inventor</i>	<i>Patent Number</i>	<i>Year</i>	<i>Patent</i>	<i>Inventor</i>
42801B	1890	Machine for the manufacture of wax coated tablets for graphophones	C. S. Tainter	510676	1894	Reproducible graphophone	C. S. Tainter
50634B	1893	Coin controlled graphophone	C. S. Tainter	670142	1900	Graphophone duplicating machine	C. S. Tainter
				730930	1903	Graphophone	C. S. Tainter

CONTENTS OF SMALL CHEST RECEIVED BY THE SMITHSONIAN INSTITUTION
FROM MRS. LAURA E. TAINTER, 1947

- Books (10) containing the home notes, volumes 1 to 8 and 11 and 12, inclusive, March 1881-November 1883. (Vols. 9, 10, and 13 were burned in a laboratory fire, September 1897.)
- Binder containing drawings and notes for multiple record duplicator, October 8, 1897-1903, and miscellaneous inquiries, fog, telegraph recorder, diet, home plans.
- Binder containing printed specifications of patents, S. Tainter, A. G. Bell, and C. A. Bell, June 26, 1880 to June 16, 1903.
- Medal, Exposition Internationale d'Electricité, Paris, 1881, marked "Tainter."
- Medal, Panama-Pacific Exposition, San Francisco, 1915, Medal of Award.
- Seven purple lapel rosettes (?), one with ribbon and palms, in boxes marked "1890." Notes in newspaper clipping.
- Records of testimony of C. S. Tainter in various suits involving the phonograph: Volta Graphophone Co. vs. Columbia Phonograph Co., no. 14733, Supreme Court of the District of Columbia, dated January 13, 1894; American Graphophone Co. vs. U. S. Phonograph Co., U. S. Circuit Court, New Jersey, dated May 14, 1895; American Graphophone Co. vs. Edw. H. Amer, U. S. Circuit Court, Northern District, Illinois, in equity, dated February 14, 1896; American Graphophone Co. vs. U. S. Phonograph Co., *et al.*, U. S. Circuit Court, New Jersey, in equity, no date; American Graphophone Co. vs. Leeds *et al.*, U. S. Circuit Court, Two District, New York, N. Y., no date; testimony marked "Questions asked in Edison Co. suits" duplicate copies, no date, no citation.

CONTENTS OF LARGE CHEST RECEIVED BY THE SMITHSONIAN INSTITUTION
FROM MRS. LAURA E. TAINTER, 1950

- Typed manuscript "Memoirs of Charles Sumner Tainter" (plus many photostats of notes and articles) 4 1/2 inches thick, pp. 1-71 to about 1878, pp. 1 to 104 to factory at Bridgeport, some pages missing.
- Box containing handwritten notes for "memoirs" includes copies of text of above (less photostats), copies of short biography; agreement creating American Graphophone Co.; letter of election to life membership in the American Association for the Advancement of Science.
- Binder exhibits of Tainter drawings in American Graphophone Co. vs. Edison Phonograph Works, vol. 1, U. S. Circuit Court, New Jersey.
- Folder—clippings and photostats relating to the machines deposited in Smithsonian.
- Certificate of appointment "Officier de l'Instruction publique," France, October 31, 1880, for exhibition of Graphophone, Exposition Universelle, 1880.
- Framed photo of Berliner & Tainter, 1909.
- Photo of Tainter, 1919.
- Separate package containing gold medal, certificate, Panama-Pacific Exposition, San Francisco, 1907; gold medal, certificate, Exposition Internationale Electrique, Paris, 1889.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 6

ON THE ORIGIN OF CLOCKWORK,
PERPETUAL MOTION DEVICES, AND THE COMPASS

Derek J. de Solla Price

POWER AND MOTION GEARING	83
MECHANICAL CLOCKS	84
MECHANIZED ASTRONOMICAL MODELS	88
PERPETUAL MOTION AND THE CLOCK BEFORE DE DONDI	108
THE MAGNETIC COMPASS AS A FOLLOW-TRAVELER FROM CHINA	110

ON THE ORIGIN OF CLOCKWORK, PERPETUAL MOTION DEVICES AND THE COMPASS

By *Derek J. de Solla Price*

Ancestor of the mechanical clock has been thought by some to be the sundial. Actually these devices represent two different approaches to the problem of timekeeping. True ancestor of the clock is to be found among the highly complex astronomical machines which man has been building since Hellenic times to illustrate the relative motions of the heavenly bodies.

This study—its findings will be used in preparing the Museum's new hall on the history of timekeeping traces this ancestry back through 2,000 years of history on three continents.

THE AUTHOR: Derek J. de Solla Price wrote this paper while serving as consultant to the Museum of History and Technology of the Smithsonian Institution's United States National Museum.

In each successive age this construction, having become lost, is, by the Sun's favour, again revealed to some one or other at his pleasure. (*Surya Siddhanta*, ed. Burgess, xiii, 18-19.)

THE HISTORIES of the mechanical clock and the magnetic compass must be accounted amongst the most tortured of all our efforts to understand the origins of man's important inventions. Ignorance has too often been replaced by conjecture, and conjecture by misquotation and the false authority of "common knowledge" engendered by the repetition of legendary histories from one generation of textbooks to the next. In what follows, I can only hope that the adding of a strong new trail and the eradication of several false and weaker ones will lead us nearer to a balanced and integrated understanding of medieval invention and the intercultural transmission of ideas.

For the mechanical clock, perhaps the greatest hindrance has been its treatment within a self-contained "history of time measurement" in which sundials, water-clocks and similar devices assume the natural role of ancestors to the weight-driven escapement clock in the early 14th century.¹ This view must presume that a generally sophisticated knowledge of gearing antedates the invention of the clock and extends back to the Classical period of Hero and Vitruvius and such authors well-known for their mechanical ingenuities.

Furthermore, even if one admits the use of clocklike gearing before the existence of the clock, it is still

¹ This traditional view is expressed by almost every history of horology. An ultimate source for many of these has been the following two classic treatments: J. Beckmann, *A history of inventions and discoveries*, 4th ed., London, 1846, vol. 1, pp. 340 ff.; A. P. Usher, *A history of mechanical inventions*, 2nd ed., Harvard University Press, 1954, pp. 191 ff., 304 ff.

necessary to look for the independent invention of the weight-drive and of the mechanical escapement. The first of these may seem comparatively trivial: anyone familiar with the raising of heavy loads by means of ropes and pulley could surely recognize the possibility of using such an arrangement in reverse as a source of steady power. Nevertheless, the use of this device is not recorded before its association with hydraulic and perpetual motion machines in the manuscripts of Ridwan, *ca.* 1200, and its use in a clock using such a perpetual motion wheel (mercury filled) as a clock escapement, in the astronomical codices of Alfonso the Wise, King of Castile, *ca.* 1272.

The second invention, that of the mechanical escapement, has presented one of the most tantalizing of problems. Without doubt, the crown and foliot type of escapement appears to be the first complicated mechanical invention known to the European Middle Ages; it heralds our whole age of machine-making. Yet no trace has been found either of a steady evolution of such escapements or of their invention in Europe, though the astronomical clock powered by a water wheel and governed by an escapement-like device had been elaborated in China for several centuries before the first appearance of our clocks. We must now rehearse a revised story of the origin of the clock as it has been suggested by recent researches on the history of gearing and on Chinese and other astronomical machines. After this we shall for the first time present evidence to show that this story is curiously related to that of the *Perpetuum Mobile*, one of the great chimeras of science, that came from its medieval origin to play an important part in more recent developments of energetics and the foundations of thermodynamics.² It is a curious mixture, all the more so because, tangled inextricably in it, we shall find the most important and earliest references to the use of the magnetic compass in the West. It seems that in revising the histories of clockwork and the magnetic compass, these con-

² There is a considerable literature dealing with the later evolution of perpetual motion devices. The most comprehensive treatment is H. Durck, *Perpetuum mobile*, London, 1861, 2nd ser., London, 1870. So far as I know there has not previously been much discussion of the history of such devices before the renaissance.



Figure 1. FRAMEWORK STRUCTURE OF THE ASTRONOMICAL CLOCK OF GIOVANNI DE DENDI OF PADUA, A. D. 1364.

siderations of perpetual motion devices may provide some much needed evidence.

Power and Motion Gearing

It may be readily accepted that the use of toothed wheels to transmit power or turn it through an axle was widespread in all cultures several centuries before the beginning of our era. Certainly, in classical times they were already familiar to Archimedes (born 287 B.C.),³ and in China actual examples of wheels and moulds for wheels dating from the 4th century

³ For the early history of gears in the West see C. M. Schoss, *Geometrie der Zahnräder*, Berlin, 1907; A. F. M. Feldhaus, *Die Geschichte der Planeteninstrumente*, Leipzig, 1912; *Phys.*, Berlin, 1914.

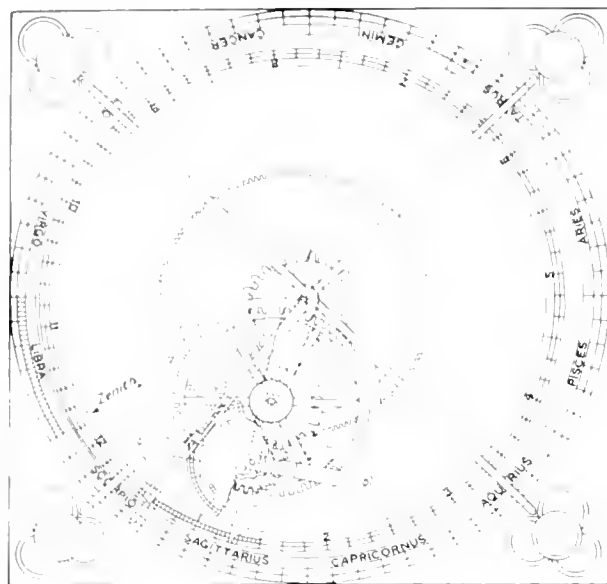


Figure 2. —ASTRONOMICAL CLOCK of de Dondi, showing gearing on the dial for Mercury and escapement crown wheel. Each of the seven side walls of the structure shown in figure 1 was fitted with a dial.

B.C. have been preserved.⁴ It might be remarked that these "machine" gear wheels are characterized by having a "round number" of teeth (examples with 16, 24 and 40 teeth are known) and a shank with a square hole which fits without turning on a squared shaft. Another remarkable feature in these early gears is the use of ratchet-shaped teeth, sometimes even twisted helically so that the gears resemble worms intermeshing on parallel axes.⁵ The existence of windmills and watermills testifies to the general familiarity, from classical times and through the middle ages, with the use of gears to turn power through a right angle.

Granted, then, this use of gears, one must guard against any conclusion that the fine-mechanical use of

⁴ A general account of these important archaeological objects will be published by E. Needham, *Science and civilisation in China*, Cambridge, 1959(?), vol. 4. The original publications (in Chinese) are as follows: Wang Chen-to, "Investigations and reproduction in model form of the south-pointing carriage and hodometer," *National Peking Academy Historical Journal*, 1937, no. 1; Liu Hsien-chou, "Chinese inventions in horological engineering," *Chino-Hua University Engineering Journal*, vol. 3, p. 1.

⁵ For illustrations of intermeshing worms in Indian cotton mills, see Matschoss, *op. cit.* (footnote 3), figs. 5, 6, 7, p. 7.

gears to provide special ratios of angular movement was similarly general and widespread. It is customary to adduce here the evidence of the hodometer (taximeter) described by Vitruvius (1st century B.C.) and by Hero of Alexandria (1st century A.D.) and the ingenious automata also described by this latter author and his Islamic followers.⁶ One may also cite the use of the reduction gear chain in power machinery as used in the geared windlass of Archimedes and Hero.

Unfortunately, even the most complex automata described by Hero and by such authors as Ridwān contain gearing in no more extensive context than as a means of transmitting action around a right angle. As for the windlass and hodometer, they do, it is true, contain whole series of gears used in steps as a reduction mechanism, usually for an extraordinarily high ratio, but here the technical details are so ethereal that one must doubt whether such devices were actually realized in practice. Thus Vitruvius writes of a wheel 4 feet in diameter and having 400 teeth being turned by a 1-toothed pinion on a cart axle, but it is very doubtful whether such small teeth, necessarily separated by about $\frac{3}{8}$ inch, would have the requisite ruggedness. Again, Hero mentions a wheel of 30 teeth which, because of imperfections, might need only 20 turns of a single helix worm to turn it! Such statements behave caution and one must consider whether we have been misled by the 16th- and 17th-century editions of these authors, containing reconstructions now often cited as authoritative but then serving as working diagrams for practical use in that age when the clock was already a familiar and complex mechanism. At all events, even if one admits without substantial evidence that such gear reduction devices were familiar from Hellenistic times onwards, they can hardly serve as more than very distant ancestors of the earliest mechanical clocks.

Mechanical Clocks

Before proceeding to a discussion of the controversial evidence which may be used to bridge this gap between the first use of gears and the fully-developed mechanical clock we must examine the other side of this gap. Recent research on the history of early me-

⁶ It is interesting to note that the Chinese hodometer was contemporary with that of Hero and Vitruvius and very similar in design. There is no evidence whatsoever upon which to decide whether there may have been a specific transmission of this invention or even a "stimulus diffusion."

mechanical clocks has demonstrated certain peculiarities most relevant to our present argument.

THE EUROPEAN TRADITION

If one is to establish a *terminus ante quem* for the appearance of the mechanical clock in Europe, it would appear that 1364 is a most reasonable date. At that time we have the very full mechanical and historical material concerning the horological masterpiece built by Giovanni de Dondi of Padua,⁷ and probably started as early as 1348. It might well be possible to set a date a few decades earlier, but in general as one proceeds backwards from this point, the evidence becomes increasingly fragmentary and uncertain. The greatest source of doubt arises from the confusion between sundials, waterclocks, hand-struck time bells, and mechanical clocks, all of which are covered by the term *horologium* and its vernacular equivalents.

Temporarily postponing the consideration of evidence prior to *ca.* 1350, we may take Giovanni de Dondi as a starting point and trace a virtually unbroken lineage from his time to the present day. One may follow the spread of clocks through Europe, from large towns to small ones, from the richer cathedrals and abbeys to the less wealthy churches.⁸ There is the transition from the tower clocks—showpieces of great institutions—to the simple chamber clock designed for domestic use and to the smaller portable clocks and still smaller and more portable pocket

⁷ A summary of the content of the manuscript sources, illustrated by the original drawings, has been published by H. Alan Lloyd, *Giovanni de Dondi's horological masterpiece, 1361*, without date or imprint (?Lausanne, 1955), 23 pp. It should be remarked that de Dondi declines to describe the workings of his crown and foliot escapement (though it is well illustrated) saying that this is of the "common" variety and if the reader does not understand such simple things he need not hope to comprehend the complexities of this mighty clock. But this may be bravado to quite a large degree.

⁸ See, for example, the chronological tables of the 14th century and the later mentions of clocks in E. Zinner, *Aus der Frühzeit der Räderuhr*, Munich, 1954, p. 29 ff. Unfortunately this very complete treatment tends to confuse the factual and legendary sources prior to the clock of de Dondi; it also accepts the very doubtful evidence of the "escapement" drawn by Villard of Honnecourt (see p. 107). An excellent and fully illustrated account of monumental astronomical clocks throughout the world is given by Alfred Ungerer, *Les horloges astronomiques*, Strasbourg, 1931, 514 pp. Available accounts of the development of the planetarium since the middle ages are very brief and especially weak on the early history: Helmut Werner, *From the Aratus globe to the Zeiss planetarium*, Stuttgart, 1957; C. A. Crommelin, "Planetaria, a historical survey," *Astronomical Horology*, 1955, vol. 1, pp. 70-75.

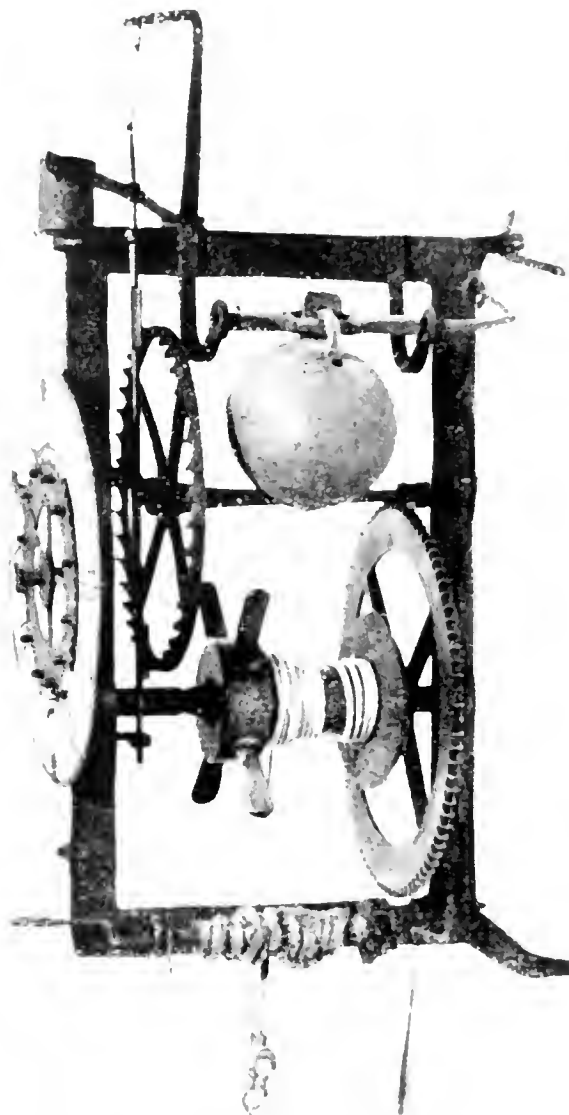


Figure 3. GERMAN WALL CLOCK, PROBABLY ABOUT 1450, showing the degeneration in complexity from that of de Dondi's clock.

watches. In mechanical refinement a similar continuity may be noted, so that one sees the cumulative effect of the introduction of the spring drive (*ca.* 1475), pendulum control (*ca.* 1650), and the anchor escapement (*ca.* 1680). The transition from de Dondi to the modern chronometer is indeed basically continuous, and though much research needs to be done on special topics, it has an historical unity and seems to conform for the most part to the general pattern of steady mechanical improvement found elsewhere in the history of technology.

Most remarkable however is the earliest period of this seemingly steady evolution. Side by side with the advances made in the earliest period extending for less than two centuries from the time of de Dondi one may see a spectacular process of degeneration or devolution. Not only is de Dondi's the earliest clock of which we have a full and trustworthy account, it is also far more complicated than any other (see figs. 1, 2) until comparatively modern times! Moreover, it was not an exceptional freak. There were others like it, and one cannot therefore reject as accidental this process of degeneration that occurs at the very beginning of the certain history of the mechanical clock in Europe.

On the basis of such evidence I have suggested elsewhere⁹ that the clock is "nought but a fallen angel from the world of astronomy." The first great clocks of medieval Europe were designed as astronomical showpieces, full of complicated gearing and dials to show the motions of the Sun, Moon and planets, to exhibit eclipses, and to carry through the involved computations of the ecclesiastical calendar. As such they were comparable to the orreries of the 18th century and to modern planetariums; that they also showed the time and rang it on bells was almost incidental to their main function. One must not neglect, too, that it was in their glorification of the rationality of the cosmos that they had their greatest effect. Through millenniums of civilization, man's understanding of celestial phenomena had been the very pinnacle of his intellect, and then as now popular exhibition of this sort was just as necessary, as striking, and as impressive. One does not have to go far to see how the paraphernalia of these early great astronomical clocks had great influence on philosophers and theologians and on poets such as Dante.

It is the thesis of this part of my argument that the ordinary time-telling clock is no affiliate of the other simple time-telling devices such as sundials, sand glasses and the elementary water clocks. Rather it should be considered as a degenerate branch from the main stem of mechanized astronomical devices (I shall call them protoclocks), a stem which can boast a continuous history filling the gap between the appearance of simple gearing and the complications of de Dondi. We shall return to the discussion of this main stem after analyzing the very recently discovered parallel stem from medieval China, which reproduced

the same evolution of mechanized astronomical devices and incidental time telling. Of the greatest significance, this stem reveals the crucial independent invention of a mechanical escapement, a feature not found in the European stem in spite of centuries of intensive historical research and effort.

THE CHINESE TRADITION

For this section I am privileged to draw upon a thrilling research project carried out in 1956 at the University of Cambridge by a team consisting of Dr. Joseph Needham, Dr. Wang Ling, and myself.¹⁰ In the course of this work we translated and commented on a series of texts most of which had not hitherto been made available in a Western tongue and, though well known in China, had not been recognized as important for their horological content. The key text with which we started was the "Hsin I Hsiang Fa Yao," or "New Design for a (mechanized) Armillary (sphere) and (celestial) Globe," written by Su Sung in A.D. 1090. The very full historical and technical description in this text enabled us to establish a glossary and basic understanding of the mechanism that later enabled us to interpret a whole series of similar, though less extensive texts, giving a history of prior development of such devices going back to the introduction of this type of escapement by I-Hsing and Liang Ling-tsan, in A.D. 725, and to what seems to be the original of all these Chinese astronomical machines, that built by Chang Hêng *ca.* A. D. 130. Filling the gaps between these landmarks are several other similar texts, giving ample evidence that the Chinese development is continuous and, at least from Chang Hêng onwards, largely independent of any transmissions from the West.

So far as we can see, the beginning of the chain in China (as indeed in the West) was the making of simple static models of the celestial sphere. An armillary sphere was used to represent the chief imaginary circles (*e.g.*, equator, ecliptic, meridians, etc.), or a solid celestial globe on which such circles could be drawn, together with the constellations of the fixed

⁹ D. J. Price, "Clockwork before the clock," *Horological Journal*, vol. 77, p. 810, and 1956, vol. 98, p. 31.

¹⁰ For the use of this material I am indebted to my co-authors. I must also acknowledge thanks to the Cambridge University Press, which in the near future will be publishing our monograph, "Heavenly Clockwork." Some of the findings of this paper are included in shorter form as background material for that monograph. A brief account of the discovery of this material has been published by J. Needham, Wang Ling, and Derek J. Price, "Chinese astronomical clockwork," *Nature*, 1956, vol. 177, pp. 600-602.

stars. The whole apparatus was then mounted so that it was free to revolve about its polar axis and another ring or a casing was added, external and fixed, to represent the horizon that provided a datum for the rising and setting of the Sun and the stars.

In the next stage, reached very soon after this, the rotation of the model was arranged to proceed automatically instead of by hand. This was done, we believe, by using a slowly revolving wheel powered by dripping water and turning the model through a reduction mechanism, probably involving gears or, more reasonably, a single large gear turned by a trip lever. It did not matter much that the time-keeping properties were poor in the long run; the model moved "by itself" and the great wonder was that it agreed with the observed heavens "like the two halves of a tally."

In the next, and essential, stage the turning of the water wheel was regulated by an "escapement" mechanism consisting of a weighbridge and trip levers so arranged that the wheel was held in check, scoop by scoop, while each scoop was filled by the dripping water, then released by the weighbridge and allowed to rotate until checked again by the trip-lever arrangement. Its action was similar to that of the anchor escapement, though its period of repose was much longer than its period of motion and, of course, its timekeeping properties were controlled not only by the mechanics of the device but also by the rate of flow of the dripping water.

The Chinese escapement may justifiably be regarded as a missing link, just halfway between the elementary clepsydra with its steady flow of water and the mechanical escapement in which time is counted by chopping its flow into cycles of action, repeated indefinitely and counted by a cumulating device. With its characteristic of saving up energy for a considerable period (about 15 minutes) before letting it go in one powerful action, the Chinese escapement was particularly suited to the driving of jackwork and other demonstration devices requiring much energy but only intermittent activity.

In its final form, as built by Su Sung after many trials and improvements, the Chinese "astronomical clock-tower" must have been a most impressive object. It had the form of a tower about 30 feet high, surmounted by an observation platform covered with a light roof (see fig. 4). On the platform was an armillary sphere designed for observing the heavens. It was turned by the clockwork so as to follow the diurnal rotation and thus avoid the distress-

ing computation caused by the change of coordinate-necessary when fixed alt-azimuth instruments were used. Below the platform was an enclosed chamber containing the automatically rotated celestial globe which so wonderfully agreed with the heavens. Below this, on the front of the tower was a miniature pagoda with five tiers; on each tier was a doorway through which, at due moment, appeared jacks who rang bells, clanged gongs, beat drums, and held tablets to announce the arrival of each hour, each quarter (they used 100 of them to the day) and each watch of the night. Within the tower was concealed the mechanism; it consisted mainly of a central vertical shaft providing power for the sphere, globe, and jackwheels, and a horizontal shaft geared to the vertical one and carrying the great water wheel which seemed to set itself magically in motion at every quarter. In addition to all this were the levers of the escapement mechanism and a pair of noias by which, once each day, the water used was pumped from a sump at the bottom to a reservoir at the top, whence it descended to work the wheel by means of a constant level tank and several channels.

There were many offshoots and developments of this main stem of Chinese horology. We are told, for example, that often mercury and occasionally sand were used to replace the water, which frequently froze in winter in spite of the application of lighted braziers to the interior of the machines. Then again, the astronomical models and the jackwork were themselves subject to gradual improvement at the time of I-Hsing, for example, special attention was paid to the demarcation of ecliptic as well as the normal equatorial coordinates; this was clearly an influx from Hellenistic-Islamic astronomy, in which the relatively sophisticated planetary mathematics had forced this change not otherwise noted in China.

By the time of the Jesuits, this current of Chinese horology, long since utterly destroyed by the perils of wars, storms, and governmental reforms, had quite been forgotten. Matteo Ricci's clocks, those gifts that aroused so much more interest than European theological teachings, were obviously something quite new to the 16th-century Chinese scholars; so much so that they were dubbed with a quite new name, "self-sounding bells," a direct translation of the word "clock" (鐘表). In view of the fact that the medieval Chinese escapement may have been the basis of European horology, it is a curious twist of fate that the high regard of the Chinese for

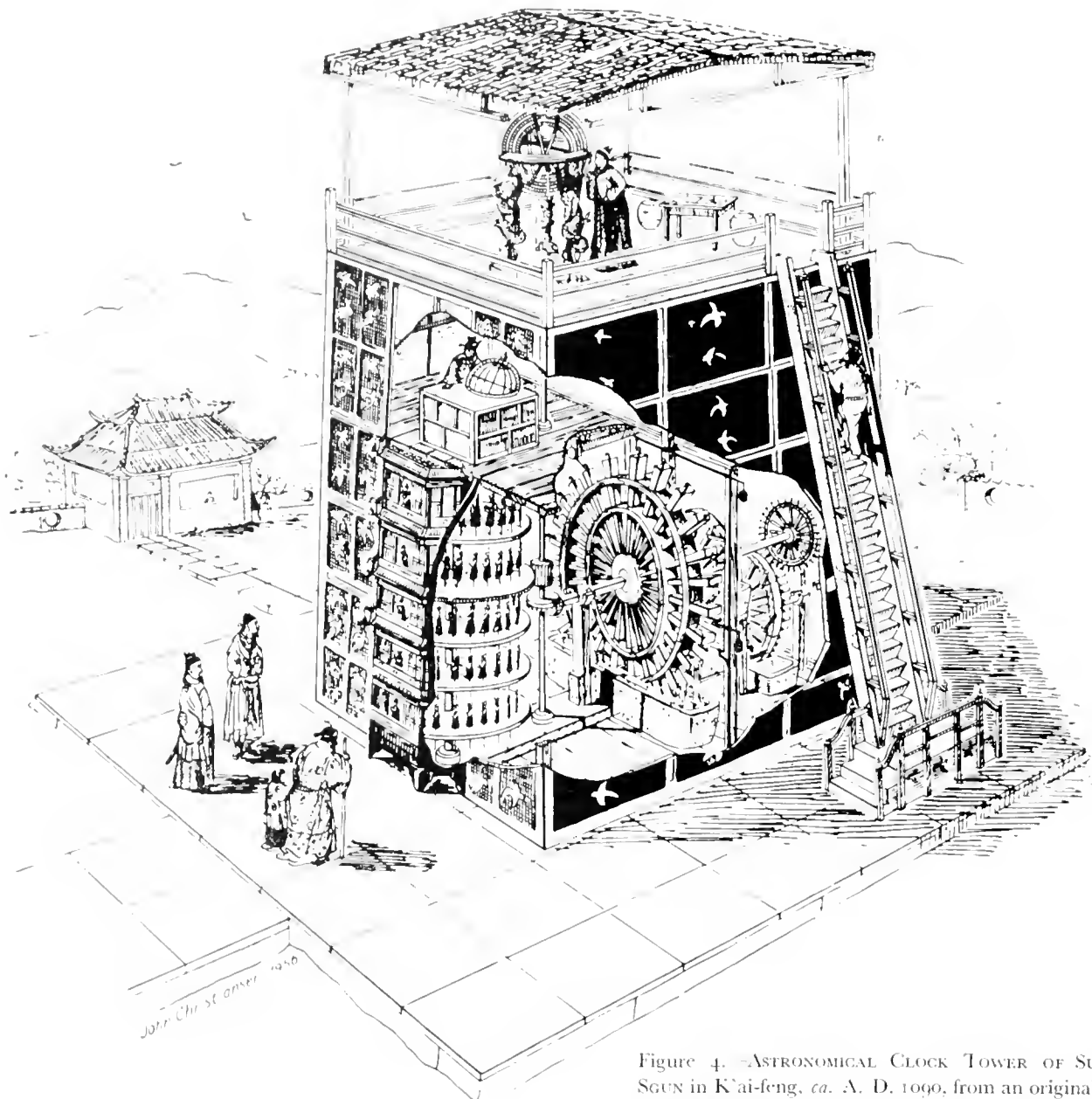


Figure 4. —ASTRONOMICAL CLOCK TOWER OF SU SONG in K'ai-feng, ca. A. D. 1090, from an original drawing by John Christiansen. (Courtesy of Cambridge University Press.)

European clocks should have prompted them to open their doors, previously so carefully and for so long kept closed against the foreign barbarians.

Mechanized Astronomical Models

Now that we have seen the manner in which mechanized astronomical models developed in China, we can detect a similar line running from Hellenistic time, through India and Islam to the medieval Europe that inherited their learning. There are many differ-

ences, notably because of the especial development of that peculiar characteristic of the West, mathematical astronomy, conditioned by the almost accidental conflux of Babylonian arithmetical methods with those of Greek geometry. However, the lines are surprisingly similar, with the exception only of the crucial invention of the escapement, a feature which seems to be replaced by the influx of ideas connected with perpetual motion wheels.

HELLENISTIC PERIOD

Most interesting and frequently cited is the bronze planetarium said to have been made by Archimedes and described in a tantalisingly fragmentary fashion by Cicero and by later authors. Because of its importance as a prototype, we give the most relevant passages in full.¹¹

Cicero's descriptions of Archimedes' planetarium are (italics supplied):

Gaius Sulpicius Gallus . . . at a time when . . . he happened to be at the house of Marcus Marcellus, his colleague in the consulship [106 B.C.], ordered the celestial globe to be brought out which the grandfather of Marcellus had carried off from Syracuse, when that very rich and beautiful city was taken [212 B.C.]. . . . Though I had heard this globe (sphaerae) mentioned quite frequently on account of the fame of Archimedes, when I saw it I did not particularly admire it; for that other celestial globe, also constructed by Archimedes, which the same Marcellus placed in the temple of Virtue, is more beautiful as well as more widely known among the people. But when Gallus began to give a very learned explanation of the device, I concluded that the famous Sicilian had been endowed with greater genius than one would imagine possible for human being to possess. For Gallus told us that the other kind of celestial globe, which was solid and contained no hollow space, was a very early invention, the first one of that kind having been constructed by Thales of Miletus, and later marked by Eudoxus of Cnidus—a disciple of Plato, it was claimed—with constellations and stars which are fixed in the sky. He also said that many years later Aratus . . . had described it in verse. . . . But this newer kind of globe, he said, on which were delineated the motions of the sun and moon and of those five stars which are called wanderers, or, as we might say, rovers [*i.e.*, the five planets], contained more than could be shown on the solid globe, and the invention of Archimedes deserved special admiration because he had thought out a way to represent accurately by a single device for turning the globe, those various and divergent movements with their different rates of speed. And when Gallus moved [*i.e.*, set in motion] the globe, it was actually true that the moon was always as many revolutions behind the sun on the *bronze contrivance* as would agree with the number of days it was behind in the sky. Thus the same eclipse of the sun happened on the globe as would actually happen, and the moon came to the point where the shadow of the earth was at the very time when the sun appeared.

¹¹ For these translations from classical authors I am indebted to Professor Loren MacKinney and Miss Harriet Lattin, who had collected them for a history, now abandoned, of planetariums. I am grateful for the opportunity of giving them the mention they deserve.

out of the motion . . . so that [106 B.C.] . . . the manuscript there . . . one

De Natura Deorum, I, iv, 2–22; Keyes' translation.

When Archimedes put together in a globe the movements of the moon, sun and five wandering planets, he brought about the same effect as that which the god of Plato did in the Timaeus when he made the world, so that one revolution produced dissimilar movements of delay and acceleration.

De Natura Deorum, I, 63.

Later descriptions from Ovid, Lactantius, Claudian, Sextus Empiricus, and Pappus, respectively, are (italics supplied):

There stands a globe suspended by a Syracusan's skill in an enclosed bronze frame, or sphere, or perhaps, in enclosed air, a small image of the immense vault of heaven; and the earth is equally distant from the top and bottom; that is brought about by its . . . the outer bronze globe's round form. The form of the temple of Vesta is similar. . . .

Ovid, *Fasti* (1st century, A.D.), VI, 277–280.

Frazer's translation.

The Sicilian Archimedes, was able to make a reproduction and model of the world in concave *bronze* (concauo aere similitudinem mundi ac figuram), in it he so arranged the *sun* and *moon* and resembling the celestial revolutions (caelestibus similes conversionibus); and while it revolved it exhibited not only the accession and recession of the sun and the waxing and waning of the moon (incrementa deminutionesque lunae), but also the unequal *movements of the stars*, whether fixed or wandering.

Lactantius, *Institutiones divinae* (4th century, A.D.), II, 5, 18.

Archimedes' sphere. When Jove looked down and saw the heavens figured in a sphere of *bronze*, he laughed and said to the other gods: "Has the power of mortal effort gone so far? Is my handiwork now mimicked in a fragile globe?" An old man of Syracuse had imitated on earth the laws of the heavens, the order of nature, and the ordinances of the gods. Some hidden influence within the sphere directs the various courses of the *stars* and actuates the lifelike mass with definite motions. A false *year* runs through a year of its own and a *toy moon* waxes and wanes month by month. Now bold invention reaches to make its own heaven revolve and sets the *stars* planets' in motion by human wit.

Claudian, *Camilla* (5th century, A.D.), 90, 11–13 VIII.

Plamant's translation.

The things that move by themselves are more wonderful than those which do not. At any rate, when we behold at Archimedes' sphere in which the sun and the rest of the stars move, we are immensely impressed by it, not by Zeus because we are amazed at the *order* of all the movements of these bodies, but by the devices and causes of the movements.

Sextus Empiricus, *Against the Physicists* (3rd century, A.D.),

IX, 115; Epps' translation.

Mechanics understand the making of spheres and know how to produce a model of the heavens (with the courses of the stars moving in circles?) by means of equal and circular motions of *water*, and Archimedes the Syracusan, according to some, knows the cause and reasons for all of these. (Pappus, 3rd century, A.D., *Books* (Hultsch' edition), VIII, 2; Epps' translation.)

A similar arrangement seems to be indicated in another mechanized globe, also mentioned by Cicero and said to have been made by Posidonius:

But if anyone brought to Scythia or Britain the globe sphaerium which our friend Posidonius of Apameia, the Stoic philosopher, recently made, in which each revolution produced the same (movements) of the *sun* and *moon* and *the* wandering stars as is produced in the sky each day and night, who would doubt that it was by exertion of reason? . . . Yet doubters . . . think that Archimedes showed more knowledge in producing movements by revolutions of a globe than nature (does) in effecting them though the copy is so infinitely inferior to the original . . . (*De natura deorum*, II, xxxiv-xxxv (88), Yonge's translation.)

In spite of the lack of sufficient technical details in any case, these mechanized globe models, with or without geared planetary indicators (which would make them highly complex machines), bear a striking resemblance to the earliest Chinese device described by Chang Hêng. One must not reject the possibility that transmission from Greece or Rome could have reached the East by the beginning of the 2nd century, A.D., when he was working. It is an interesting question, but even if such contact actually occurred, very soon afterwards, as we shall see, the western and eastern lines of evolution parted company and evolved so far as can be seen, quite independently until at least the 12th century.

The next Hellenistic source of which we must take note is a fragmentary and almost unintelligible chapter in the works of Hero of Alexandria. Alone and unconnected with his other chapters this describes a model which seems to be static, in direct contrast to all other devices which move by pneumatic and hydrostatic pressures; it may well be conjectured that in its original form this chapter described a mechanized rather than a static globe:

The World represented in the Centre of the Universe: Construction of a transparent globe containing air and *water*, and also of a smaller globe, in the centre, in imitation of the World. Two hemispheres of glass are made; one of them is covered with a plate of bronze, in the middle of which is a round hole. To fit this hole a light ball, of small

size, is constructed, and thrown into the water contained in the other hemisphere; the covered hemisphere is next applied to this, and, a certain quantity of the liquid having been removed from the water, the intermediate space will contain the ball; thus by the application of the second hemisphere what was proposed is accomplished.

Pneumatics, XLIII. Woodcroft's translation.

It will be noted that these earliest literary references are concerned with pictorial, 3-dimensional models of the universe, moved perhaps by hand, perhaps by waterpower; there is no evidence that they contained complicated trains of gears, and in the absence of this we may incline to the view that in at least the earliest such models, gearing was not used.

The next developments were concerned on the one hand with increasing the mathematical sophistication of the model, on the other hand with its mechanical complexity. In both cases we are most fortunate in having archaeological evidence which far exceeds any literary sources.

The mathematical process of mapping a sphere onto a plane surface by stereographic projection was introduced by Hipparchus and had much influence on astronomical techniques and instruments thereafter. In particular, by the time of Ptolemy (*ca.* A.D. 120) it had led to the successive inventions of the anaphoric clock and of the planispheric astrolabe.¹² Both these devices consist of a pair of stereographic projections, one of the celestial sphere with its stars and ecliptic and tropics, the other of the lines of altitude and azimuth as set for an observer in a place at some particular latitude.

In the astrolabe, an openwork metal rete containing markings for the stars, etc., may be rotated by hand over a disc on which the lines of altitude and azimuth are inscribed. In the anaphoric clock a disc engraved with the stars is rotated automatically behind a fixed grille of wires marking lines of altitude and azimuth. Power for rotating the disc is provided by a float rising in a clepsydra jar and connected, by a rope or chain passing over a pulley to a counterweight or by a rack and pinion, to an axle which supported the rotating disc and communicated this motion to it.¹³

¹² A. G. Drachmann, "The plane astrolabe and the anaphoric clock," *Centaurus*, 1954, vol. 3, pp. 183-189.

¹³ A fuller description of the anaphoric clock and cognate waterlocks is given by A. G. Drachmann, "Ktesibios, Philon and Heron," *Acta Historica Scientiarum Naturalium et Medicinalium*, Copenhagen, 1948, vol. 4.



Figure 5.—PLATE OF SALZBURG ANAPHORIC CLOCK, a reconstruction (see footnote 14) based on a photograph of the remaining fragment. (Courtesy of Oxford University Press.)

Parts of two such discs from anaphoric clocks have been found, one at Salzburg¹⁴ and one at Grand in the Vosges,¹⁵ both of them dating from the 2nd century A. D. Fortunately there is sufficient evidence to reconstruct the Salzburg disc and show that it must have been originally about 170 cm. in diameter, a heavy sheet of bronze to be turned by the small power provided by a float, and a large and impressive device when working (see fig. 5).

¹⁴ First published by O. Benndorf, E. Weiss, and A. Rehm, *Jahreshefte des ost-reichischen archäologischen Instituts*, II, 1903, vol. 6, pp. 32-49. I have given further details of its construction in *A history of technology*, ed. Singer, Holmyard, and Hall, 1957, vol. 3, pp. 604-605.

¹⁵ L. Mase-Werly, *Mémoires de la Société Archéologique des Antiquaires de France*, 1887, vol. 48, pp. 170-178.

Literary accounts of the anaphoric clock have been analyzed by Drachmann; there is no evidence of the representation of planets moved either by hand or by automatic gearing, only in the important case of the sun was such a feature included of necessity. A model "sun" on a pin could be plugged in to any one of 360 holes drilled in at equal intervals along the band of the ecliptic. This pin could be moved each day so that the anaphoric clock kept step with the seasonal variation of the times of sunrise and sunset and the lengths of day and night.

The anaphoric clock is not only the origin of the astrolabe and of all later planetary models; it is also the first clock dial, setting a standard for "clockwise" rotation, and leaving its mark in the rotating dial and stationary pointer found on the earliest time-

keeping clocks before the change was made to a fixed dial and moving hand.

We come finally to a piece of archaeological evidence that surpasses all else. Though badly preserved and little studied it might well be the most important classical object ever found; entailing a complete re-estimation of the technical prowess of the Hellenistic Greeks. In 1901 a sunken treasure ship was discovered lying off the island of Antikythera, between Greece and Crete,¹⁶ Many beautiful classical works of statuary were recovered from it, and these are now amongst the greatest treasures of the National Museum at Athens, Greece. Besides these obviously desirable art relics, there came to the surface some curious pieces of metal, accompanied by traces of what may have been a wooden casing. Two thousand years under the sea had reduced the metal to a mess of corroded fragments of plates,

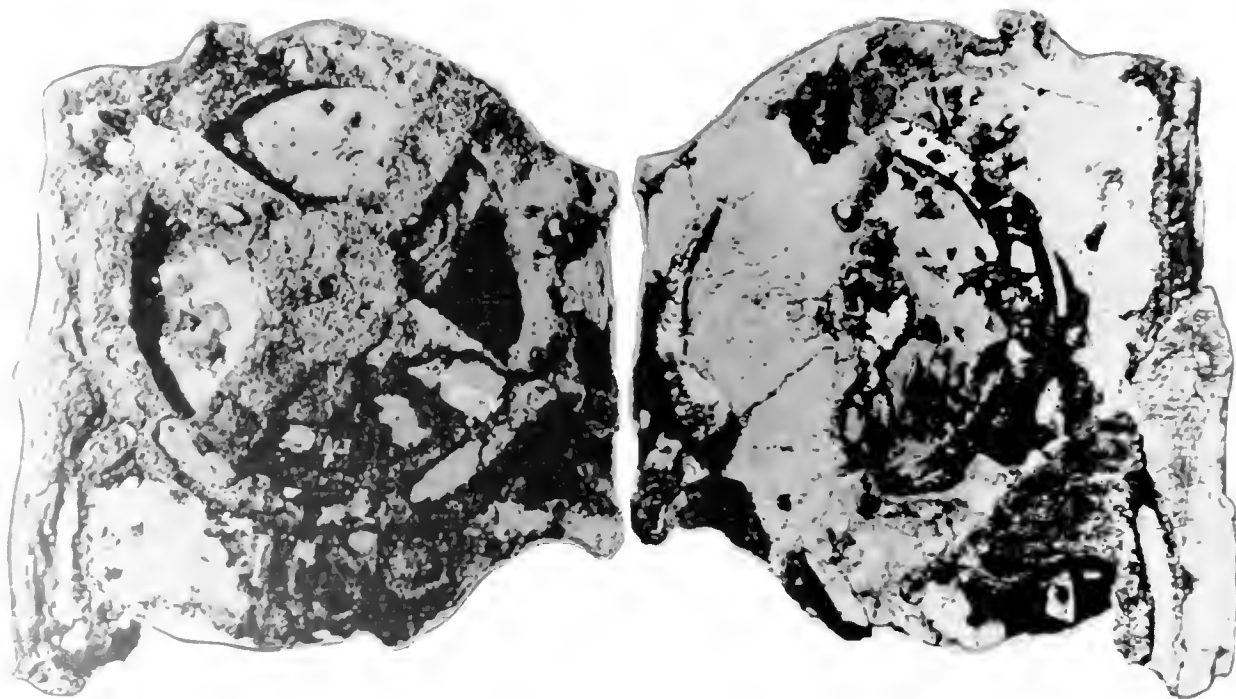
¹⁶ The first definitive account of the Antikythera machine was given by Perikles Rediadiis in J. Svoronos, *Das Athenen Nationalmuseum*, Athens, 1908, Textband I, pp. 43-51. Since then, other photographs (mostly very poor) have appeared, and an attempt at a reconstruction has been made by Rear Admiral Jean Theopphanidis, *Praktika tes Akademias Athenon*, Athens, 1934, vol. 9, pp. 140-149 (in French). I am deeply grateful to the Director of the Athens National Museum, M. Karouzos, for providing me with an excellent new set of photos, from which figures 6-8 are now taken.

powdered verdigris, and still recognizable pieces of gear wheels.

If it were not for the established dates for other treasure from this ship, especially the minor objects found, and for traces of inscriptions on this metal device written in letters agreeing epigraphically with the other objects, one would have little doubt in supposing that such a complicated piece of machinery dated from the 18th century, at the earliest. As it is, estimates agree on ca. 65 B.C. ± 10 years, and we can be sure that the machine is of Hellenistic origin, possibly from Rhodes or Cos.

The inscriptions, only partly legible, lead one to believe that we are dealing with an astronomical calculating mechanism of some sort. This is born out by the mechanical construction evident on the fragments. The largest one (fig. 6) contains a multiplicity of gearing involving an annular gear working epicyclic gearing on a turntable, a crown wheel, and at least four separate trains of smaller gears, as well as a 4-spoked driving wheel. One of the smaller fragments (fig. 7, bottom) contains a series of movable rings which may have served to carry movable scales on one of the three dials. The third fragment (fig. 7, top) has a pair of rings carefully engraved and gradu-

Figure 6.—ANTIKYTHERA MACHINE, LARGEST FRAGMENT. (Photo courtesy of National Museum, Athens.)



ated in degrees of the zodiac (this is, incidentally, the oldest engraved scale known, and micrometric measurements on photographs have indicated a maximum inaccuracy of about $1\frac{1}{2}^\circ$ in the 45° present).

Unfortunately, the very difficult task of cleaning the fragments is slow, and no publication has yet given sufficient detail for an adequate explanation of this object. One can only say that although the problems

of restoration and mechanical analysis are peculiarly great, this must stand as the most important scientific artifact preserved from antiquity.

Some technical details can be gleaned however. The shape of the gear teeth appears to be almost exactly equilateral triangles in all cases (fig. 8), and square shanks may be seen at the centers of some of the wheels. No wheel is quite complete enough for a count of gear teeth, but a provisional reconstruction by Theopphanidis (fig. 9) has shown that the appearances are consistent with the theory that the

Figure 7.—ANTIKYTHERA MACHINE. TWO SMALLER FRAGMENTS. (Photo courtesy of National Museum, Athens.)



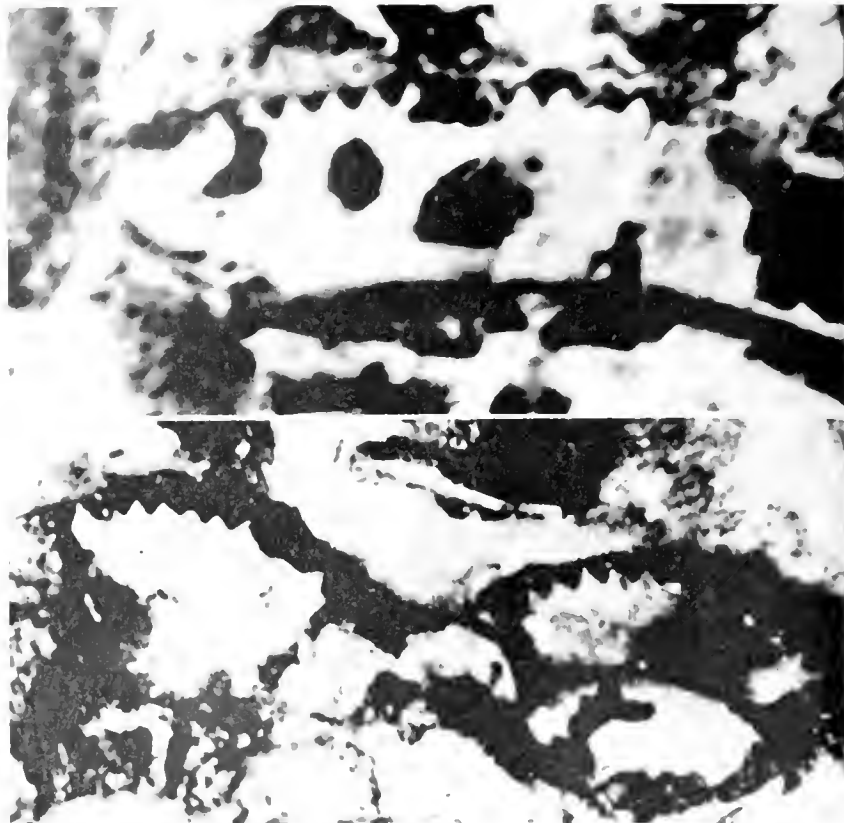


Figure 8.—ANTIKYTHERA MACHINE, DETAIL FROM FIGURE 6, showing gearing. (Photo courtesy of National Museum, Athens.)

purpose of the gears was to provide the correct angular ratios to move the sun and planets at their appropriate relative speeds.

Thus, if the evidence of the Antikythera machine is to be taken at its face value, we have, already in classical times, the use of astronomical devices as complicated as any clock. In any case, the material supplied

by the works ascribed to Archimedes, Hero, and Vitruvius, and the more certain evidence of the anaphoric clocks is sufficient to show that there was a strong classical tradition of such machines, a tradition that inspired, even if it did not directly influence, later developments in Islam and Europe on the one side, and, just possibly, China on the other.

Note added in proof:

Since the above lines were written, I have been privileged to make a full examination of the fragments in the National Museum in Athens. As a result we can read much more inscription and make out many more details of the mechanism. The cleaning and disentangling of the fragments by the museum staff has proceeded to the stage where one can assert much more positively that the device

was an astronomical computer for sidereal, solar, lunar, and possibly also planetary phenomena. (See my article in the *Scientific American*, June 1959, vol. 200, No. 6, pp. 60-67). Relevant to the present study, it must also be noted at this point that the machine is now shown to be strongly related to the geared astrolabe of al-Birun and thereby the Hellenistic, Islamic, and European developments are drawn together even more tightly.

Thus now turn our attention to those civilizations which were intermediaries, geographically and culturally, between Greece and medieval Europe, and between both of these and China. From India there are only two references, very closely related and

appearing in the best known astronomical texts in connection with descriptions of the armillary sphere and celestial globe. These texts are both quite garbled, but so far as one may understand them, it seems that the types of spheres and globes mentioned

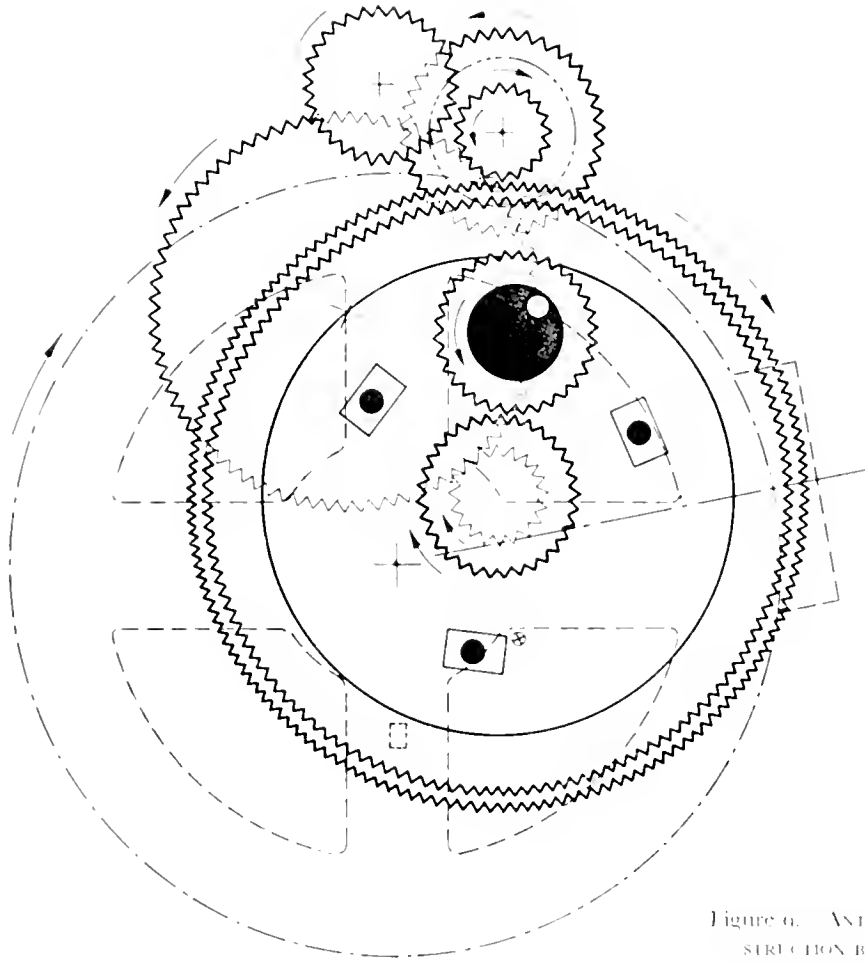


Figure 6. ANTIKYTHERA MACHINE, PARTIAL RECONSTRUCTION BY THEOPHANIDIS (see footnote 16).

are more akin to those current in China than in the West. The relevant portions of text are as follows (italics supplied):

The circle of the horizon is midway of the sphere. As covered with a casing and as left uncovered, it is the sphere surrounded by Lokāloka (the mountain range which formed the boundary of the universe in puranic geography). By the application of water is made ascertainment of the revolution of time. One may construct a sphere-instrument combined with quicksilver: this is a mystery; if plainly described, it would be generally intelligible in the world. Therefore let the supreme sphere be constructed according to the instruction of the preceptor (guru). In each successive age this construction, having become lost, is, by the Sun's favour, again revealed to some one or other, at his pleasure. So also, one should construct instruments in order to ascertain time. When quite alone, one should apply quicksilver to the wonder-causing instrument. By the gnomon, staff, arc, wheel, instruments for taking the shadow of various kinds, . . . By water-instruments, the

vessel, by the peacock, man, monkey, and by stringed sand-receptacles one may determine time accurately. Quicksilver-holes, water, and cords, and oil and water, mercury and sand are used in these; these applications, too, are difficult.

S702.8. 177a. xiii. 17-22.

L. Burgess' translation, New Haven, 1960.

A self-revolving instrument (or swayavadha yantra): Make a wheel of light wood and in its circumference put hollow spokes all having holes of the same diameter, and let them be placed at equal distances from each other, and let them also be placed at an angle varying somewhat from the perpendicular. Then half fill these hollow spokes with mercury; the wheel thus filled will, when placed on pillars supported by two posts, revolve of itself.

Or scoop out a canal in the rim of the wheel, and then plastering leaves of the Lal tree over this canal with mud, fill one half of this canal with water, and the other half with mercury; till the water begins to come out and then

the orifice left open for filling the wheel. The wheel will then revolve of itself, drawn around by the water.

Description of a syphon: Make up a tube of copper or other metal, and bend it in the form of an Ankus'a or elephant hook, fill it with water and stop up both ends. And then putting one end into a reservoir of water let the other end remain suspended outside. Now uncork both ends. The water of the reservoir will be wholly sucked up and fall outside.

Now attach to the rim of the before described self-revolving wheel a number of water-pots, and place the wheel and these pots like the water wheel so that the water from the lower end of the tube flowing into them on one side shall set the wheel in motion, impelled by the additional weight of the pots thus filled. The water discharge from the pots as they reach the bottom of the revolving wheel, should be drawn off into the reservoir before alluded to by means of a water-course or pipe.

The self-revolving machine [mentioned by *Lalla*, etc.] which has a tube with its lower end open is a vulgar machine on account of its being dependant, because that which manifests an ingenious and not a rustic contrivance is said to be a machine.

And moreover many self-revolving machines are to be met with, but their motion is procured by a trick. They are not connected with the subject under discussion. I have been induced to mention the construction of these, merely because they have been mentioned by former astronomers.

Siddhānta Shromāṇī, xi. 50-57. L. Wilkinson's translation, revised by Bāpū deva Śhāstri. Calcutta, 1861.

Before proceeding to an investigation of the content of these texts it is of considerable importance to establish dates for them, though there are many difficulties in establishing any chronology for Hindu astronomy. The *Sūrya Siddhānta* is known to date, in its original form, from the early Middle Ages, *ca.* 500. The section in question is however quite evidently an interpolation from a later recension, most probably that which established the complete text as it now stands: it has been variously dated as *ca.* 1000 to *ca.* 1150 A. D. The date of the *Siddhānta Shromāṇī* is more certain for we know it was written in about 1150 by Bhāskara (born 1114). Thus both these passages must have been written within a century of the great clocktower made by Su Sung. The technical details will lead us to suppose there is more than a temporal connection.

We have already noted that the armillary spheres and celestial globes described just before these extracts are more similar in design to Chinese than to Ptolemaic practice. The mention of mercury and of sand as alternatives to water for the clock's fluid is another

feature very prevalent in Chinese but absent in the Greek texts. Both texts seem conscious of the complexity of these devices and there is a hint (it is lost and revealed) that the story has been transmitted, only half understood, from another age or culture. It should also be noted that the mentions of cords and strings rather than gears, and the use of spheres rather than planispheres would suggest we are dealing with devices similar to the earliest Greek models rather than the later devices, or with the Chinese practice.

A quite new and important note is injected by the passage from the Bhāskara text. Obviously intrusive in this astronomical text we have the description of two "perpetual motion wheels" together with a third, castigated by the author, which helps its perpetuity by letting water flow from a reservoir by means of a syphon and drop into pots around the circumference of the wheel. These seem to be the basis also, in the extract from the *Sūrya Siddhānta*, of the "wonder-causing instrument" to which mercury must be applied.

In the next sections we shall show that this idea of a perpetual motion device occurs again in conjunction with astronomical models in Islam and shortly afterwards in medieval Europe. At each occurrence, as here, there are echoes of other cultures. In addition to those already mentioned we find the otherwise mysterious "peacock, man and monkey," cited as parts of the jackwork of astronomical clocks of Islam, associated with the weight drive so essential to the later horology in Europe.

We have already seen that in classical times there were already two different types of proto-clocks; one, which may be termed "nonmathematical," designed only to give a visual aid in the conception of the cosmos, the other, which may be termed "mathematical" in which stereographic projection or gearing was employed to make the device a quantitative rather than qualitative representation. These two lines occur again in the Islamic culture area.

Nonmathematical proto-clocks which are scarcely removed from the classical forms appear continuously through the Byzantine era and in Islam as soon as it recovered from the first shocks of its formation. Procopius (died *ca.* 535) describes a monumental water clock which was erected in Gaza *ca.* 500.¹⁷ It contained impressive jackwork, such as a Medusa

¹⁷ H. Diels Über die von Prokop beschriebene Kunstuhr von Gaza. *Abhandlungen, Akademie der Wissenschaften, Berlin, Philos.-Hist. Klasse*, 1917, No. 7.

head which rolled its eyes every hour on the hour, exhibiting the time through lighted apertures and showing mythological interpretations of the cosmos. All these effects were produced by Heronic techniques, using hydraulic power and puppets moved by strings, rather than with gearing.

Again in 807 a similarly marvelous exhibition clock made of bronze was sent by Harun-al-Rashid to the Emperor Charlemagne: it seems to have been of the same type, with automata and hydraulic works. For the succeeding few centuries, Islam was in its Golden Age of development of technical astronomy (*ca.* 950-1150) and attention may have been concentrated on the more mathematical proto-clocks. Towards the end of the 12th century, however, there was a revival of the old tradition, mainly at the court of the Emperor Saladin (1146-1173) when a great automaton water clock, more magnificent than any hitherto, was erected in Damascus. It was rebuilt, after 1168, by Muhammad b. 'Ali b. Rustum, and repaired and improved by his son, Fakhr ad-din Ridwan b. Muhammad,¹⁸ who is most important as the author of a book which describes in considerable technical detail the construction of this and other proto-clocks. Closely associated with his book one also finds texts dealing with perpetual-motion devices, which we shall consider later.

During the century following this horological exuberance in Damascus, the center of gravity of Islamic astronomy shifted from the East to the Hispano-Moorish West. At the same time there comes more evidence that the line of mathematical proto-clocks had not been left unattended. This is suggested by a description given by Trithemius of another royal gift from East to West which seems to have been different from the automata and hydraulic devices of the tradition from Procopius to Ridwan:¹⁹

In the same year [1232] the Saladin of Egypt sent by his ambassadors as a gift to the emperor Frederic a valuable machine of wonderful construction worth more than five thousand ducats. For it appeared to resemble internally a celestial globe in which figures of the sun, moon, and other planets formed with the greatest skill moved, being impelled by weights and wheels, so that performing their course in certain and fixed intervals they pointed out the hour night and day with infallible certainty; also the twelve signs of the zodiac with certain appropriate char-

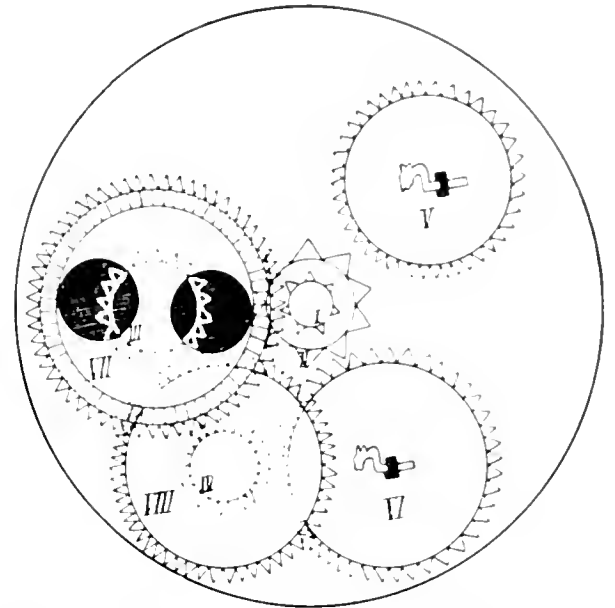


Figure 10. CALENDRIAL GEARING, DESIGNED BY AL-BIRUNI, *ca.* A. D. 1000. The gear train count is $40 : 10 = 7 : 50 = 19 : 59 = 24 : 48$. The gear of 48 therefore makes 19 (annual) rotations while that of 19 : 59 shows 118 double lunations of 29 : 30 : 59 days. The gear of 40 shows a (lunar) rotation in exactly 28 days, and the center pinions 7 : 10 rotate in exactly one week. After Wiedemann (see footnote 20).

acters, moved with the firmament, contained within themselves the course of the planets.

The phrase "resembled internally" is of especial interest in this passage; it may perhaps arise as a mistranslation of the technical term for stereographic projection of the sphere, and if so the device might have been an anaphoric clock or some other astrolabic device.

This is made more probable by the existence of a specifically Islamic concentration on the astrolabe, and on its planetary companion instrument, the equatorium, as devices for mechanizing computation by use of geometrical analogues. The ordinary planispheric astrolabe, of course, was known in Islam from its first days until almost the present time. From the time of al-Biruni (*ca.* 1000) significantly, perhaps, he is well known for his travel account of India—there is remarkable innovation.

Most cogent to our purpose is a text, described for the first time by Wiedemann,²⁰ in which al-Biruni

¹⁸ L. A. Mayer, *Islamic Astrolabists and their works*, Geneva, 1956, p. 62.

¹⁹ The translation which follows is quoted from J. Beckmann, *op. cit.* (footnote 1), p. 349.

²⁰ E. Wiedemann, "Ein Instrument das die Bewegung von Sonne und Mond darstellt, nach al-Biruni," *Die Welt*, 1913, vol. 4, p. 5.



FIGURE 11. GEARED ASTROLABE BY MUHAMMAD B. ABĪ BAKR OF ISFĪHĀN, A. D. 1221-1222.
(Photo courtesy of Science Museum, London.)

explains how a special train of gearing may be used to show the revolutions of the sun and moon at their relative rates and to demonstrate the changing phase of the moon, features of fundamental importance in the Islamic (lunar) calendrical system. This device necessarily uses gear wheels with a "non-round" number of teeth (e.g., 7, 19, 59) as dictated by the astronomical constants involved (see fig. 10). The teeth are shaped like equilateral triangles and square shanks are used, just as with the Antikythera machine. Horse-shaped wheels are used for fixing; a tradition borrowed from the horse-shaped *Enz* used to fasten the mechanical clock face. Of special interest for us is the lunar phase diagram, which is just the same in

form and structure as the lunar volvelle that occurs later in horology and is still so commonly found today, especially as a decoration for the dial of grandfather clocks.

Biruni's calendrical machine is the earliest complicated geared device on record and it is therefore all the more significant that it carries a feature found in later clocks. From the manuscript description alone one could not tell whether it was designed for automatic action or merely to be turned by hand. Fortunately this point is made clear by the most happy survival of an intact specimen of this very device, without doubt the oldest geared machine in existence in a complete state.

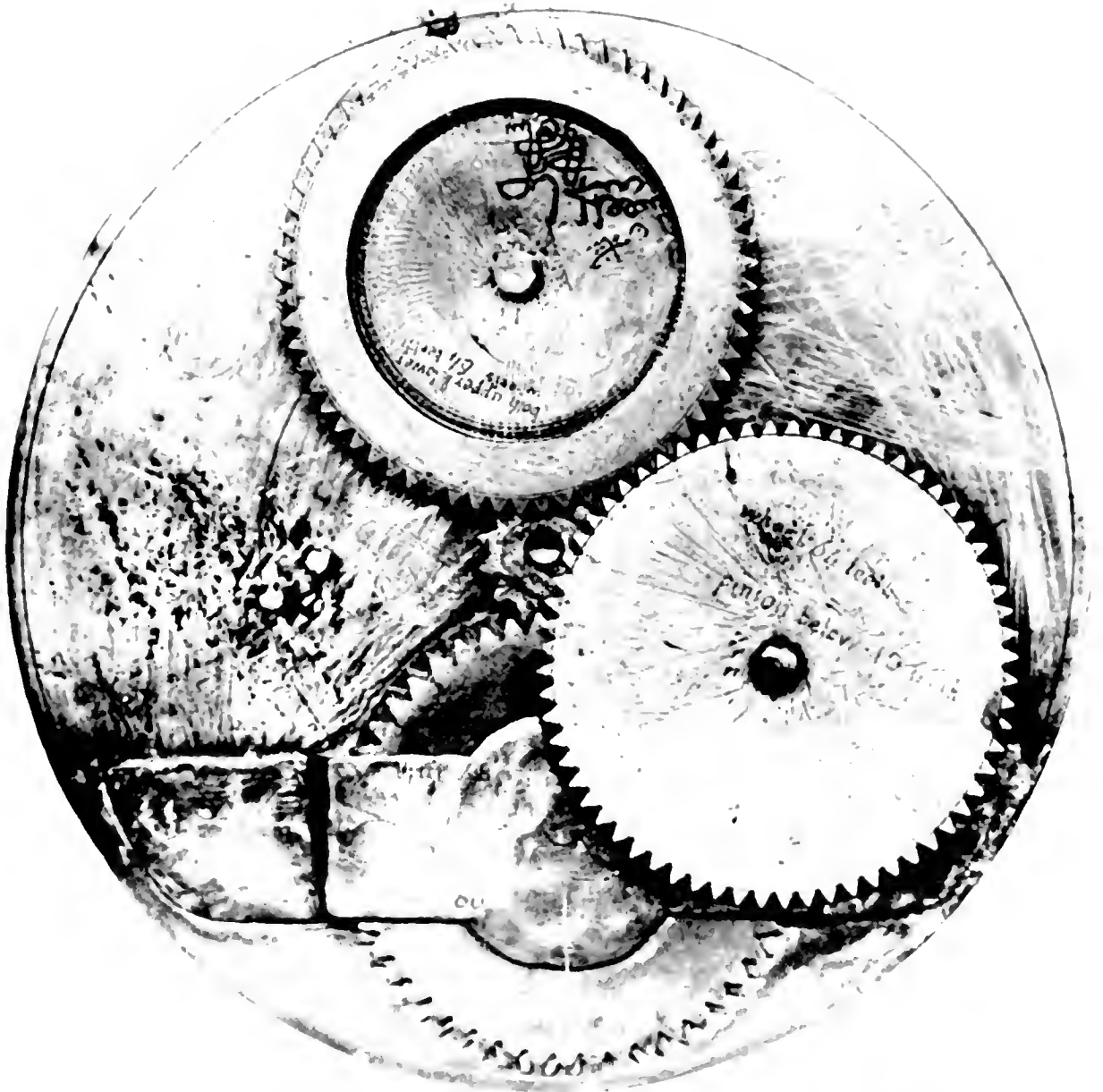


Figure 12. GEARING FROM ASTROLABE SHOWN IN FIGURE 11. The gear train count is as follows: $48 \cdot 13 \cdot 8 \cdot 64 \cdot 64 \cdot 10 \cdot 60$. The pinion of B has been incorrectly replaced by a more modern pinion of 10. The gear of B should make 13 lunar rotations while the double gear of $64 \cdot 64$ makes 6 revolutions of double months (of 20–30 days), and the gear of 60 makes a single turn in the hegiral year of 354 days. (Photocopy of *Science Museum, I. 17*.)

This landmark in the history of science and technology is now preserved at the Museum of the History of Science, Oxford, England.²¹ It is an astro-

²¹ I acknowledge with thanks to the Curator of that museum the permission to reproduce photographs of this instrument. It is item 5 in R. L. Gunther, *Astrolabes of the world*, Oxford, 1952.

labre, dated 1221–22, and signed by the maker, Muḥammad b. Abī Bakr (died 1231–32 of Isfahan, Persia; see figs. 11 and 12). The very close resemblance to the design of Burūnī is quite apparent, though the gearing has been simplified very cleverly so that only one wheel has an odd number of teeth (13), the rest being

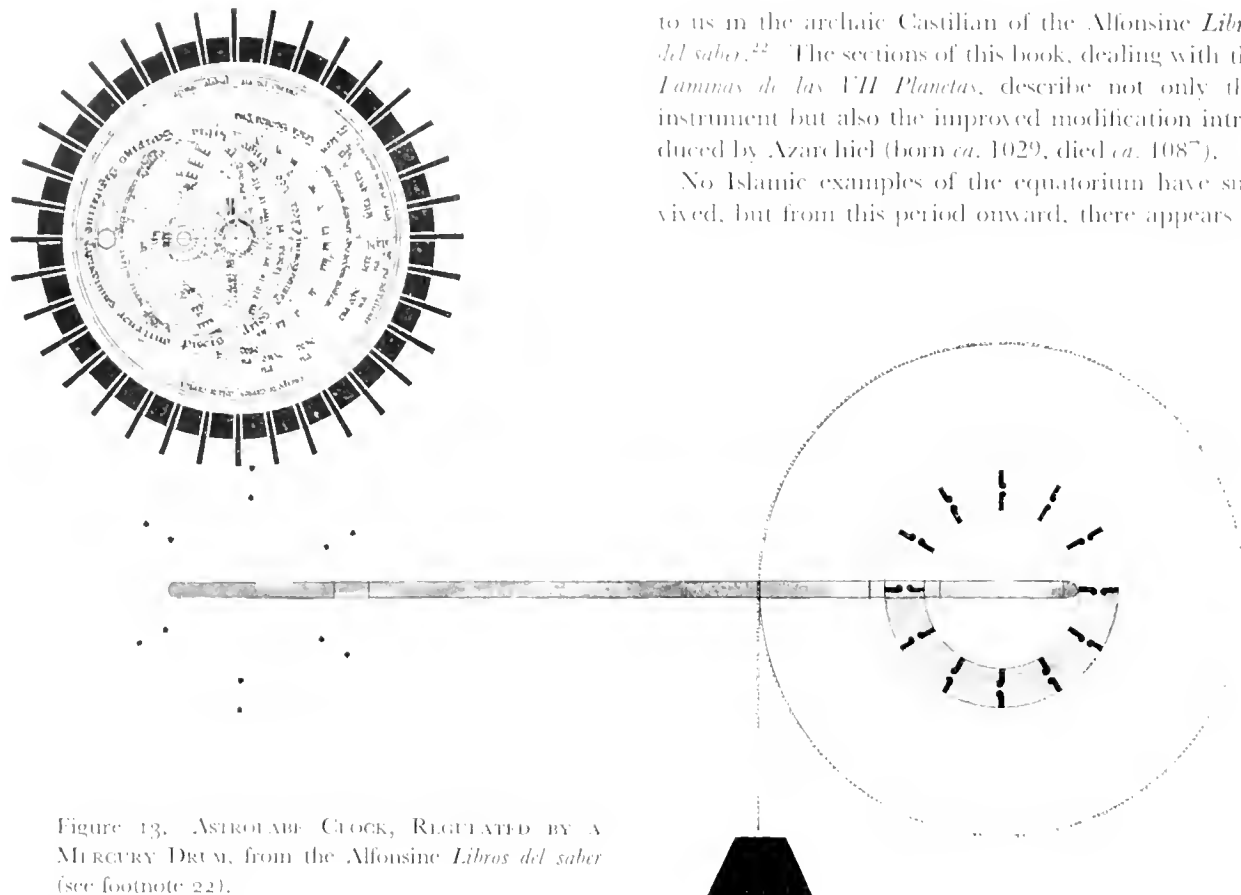


Figure 13. ASTROLABE CLOCK, REGULATED BY A MERCURY DRUM, from the *Alfonsine Libros del saber* (see footnote 22).

much easier to mark out geometrically (e.g., 10, 48, 60, and 64 teeth). The lunar phase volvelle can be seen through the circular opening at the back of the astrolabe. It is quite certain that no automatic action is intended; when the central pivot is turned, by hand, probably by using the astrolabe rete as a "handle," the calendrical circles and the lunar phase are moved accordingly. Using one turn for a day would be too slow for useful re-setting of the instrument, in practice a turn corresponds more nearly to an interval of one week.

In addition to this geared development of the astrolabe, the same period in Islam brought forth a new device, the equatorium, a mechanical model designed to simulate the geometrical constructions used for finding the positions of the planets in Ptolemaic astronomy. The method may have originated already in classical times, a simple device being described by Proclus Diadochus (ca. 450), but the first general, though crude, planetary equatorium seems to have been described by Abulcāsim Abnācāhīm (ca. 1027) in Granada; it has been handed down

to us in the archaic Castilian of the Alfonsine *Libros del saber*.²² The sections of this book, dealing with the *Laminas de las VII Planetas*, describe not only this instrument but also the improved modification introduced by Azarchiel (born ca. 1029, died ca. 1087).

No Islamic examples of the equatorium have survived, but from this period onward, there appears to

have been a long and active tradition of them, and ultimately they were transmitted to the West, along with the rest of the Alfonsine corpus. More important for our argument is that they were the basis for the mechanized astronomical models of Richard of Wallingford (ca. 1320) and probably others, and for the already mentioned great astronomical clock of de Dondi. In fact, the complicated gearwork and dials of de Dondi's clock constitute a series of equatoria, mechanized in just the same way as the calendrical device described by Biruni.

It is evident that we are coming nearer now to the beginning of the true mechanical clock, and our last step, also from the Alfonsine corpus of western Islam, provides us with an important link between the ana-

²² Abulcāsim Abnācāhīm, *Libros del saber*, edition by Rico y Sinobas, Madrid, 1866, vol. 3, pp. 241-271. The design of the instrument has been very fully discussed by A. Wegener, "Die astronomischen Werke Alfons X," *Bibliotheca Mathematica*, 1905, pp. 129-189. A more complete discussion of the historical evolution of the equatorium is given in Derek J. Price, *The equatorie of the planetis*, Cambridge (Eng.), 1955, pp. 119-133.

phoric clock, the weight drive, and a most curious perpetual-motion device, the mercury wheel, used as an escapement or regulator. The Alfonsine book on clocks contains descriptions of five devices in all, four of them being due to Isaac b. Sid (two sundials, an automaton water-clock and the present mercury clock) and one to Samuel ha-Levi Adulafia (a candle clock)—they were probably composed just before ca. 1276–77.

The mercury clock of Isaac b. Sid consists of an astrolabe dial, rotated as in the anaphoric clock, and fitted with 30 leaf-shaped gear teeth (see fig. 13).

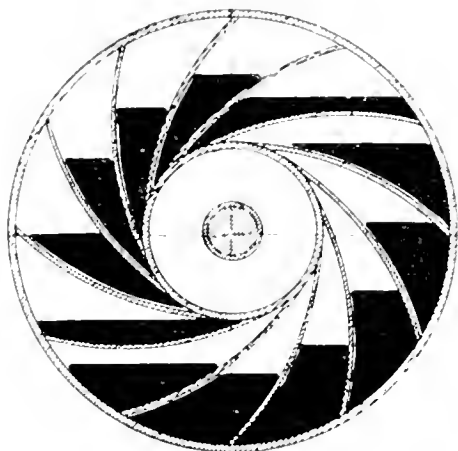


Figure 14. ISLAMIC PERPETUAL MOTION WHEEL, after manuscript cited by Schmeller (see footnote 26).

These are driven by a pinion of 6 leaves mounted on a horizontal axle (shown very diagrammatically in the illustration) and at the other end of this axle is a wheel on which is mounted the special mercury drum which is powered by a normal weight drive.

It is the mercury drum which forms the most novel feature of this device; the fluid, constrained in 12 chambers so as to just fill 6 of them, must slowly filter through small holes in the constraining walls. In practice, of course, the top mercury surfaces will not be level, but higher on the right so as to balance dynamically the moment of the applied weight on its driven rope. This curious arrangement shows point of resemblance to the Indian “mercury-holes,” to the

perpetual-motion devices found in the medieval European tradition and also in the texts associated with Ridwān, which we shall next examine.

It is of the greatest interest to our theme that the Islamic contributions to horology and perpetual motion seem to form a closely knit corpus. A most important series of horological texts, including those of Ridwān and al-Jazari, have been edited by Wiedemann and Hauser.²³ Other Islamic texts give versions of the water clocks and automata of Archimedes and of Hero and Philo of Alexandria.²⁴ In at least three cases²⁵ these texts are found also associated with texts

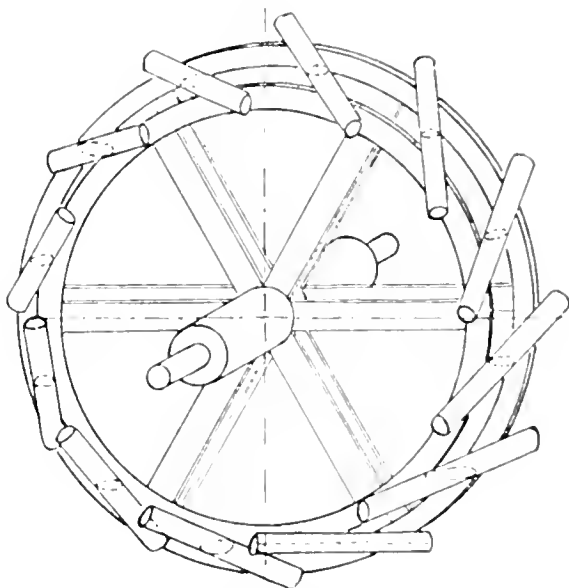


Figure 15. ANOTHER PERPETUAL MOTION WHEEL, after the text cited in figure 14.

describing perpetual-motion wheels and other hydraulic devices. Three manuscripts of this type have been published in German translation by Schmeller.²⁶

²³ E. Wiedemann, and F. Hauser, “Über die Uhren im Bereich d. islamischen Kultur,” *Verh. d. Abh. d. Königl. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher zu Halle*, 1915, vol. 100, no. 5.

²⁴ E. Wiedemann, and F. Hauser, *Die Uhr des Archimedes und zwei andere Vorrichtungen*, Halle, 1918.

²⁵ The manuscripts in question are as follows: Gotha, Kat. v. Persch. 3, 18, no. 1348; Oxford, Cod. 954; Leiden, Kat. 3, 288, no. 1313, Cod. 499 Wam; and another similar, Kat. 3, 291, no. 1415, Cod. 93 Gol.

²⁶ H. Schmeller, *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern*, Erlangen, 1922; *Übersetzungen zur Geschichte der Naturwissenschaften seit der Michel. no. 6.*

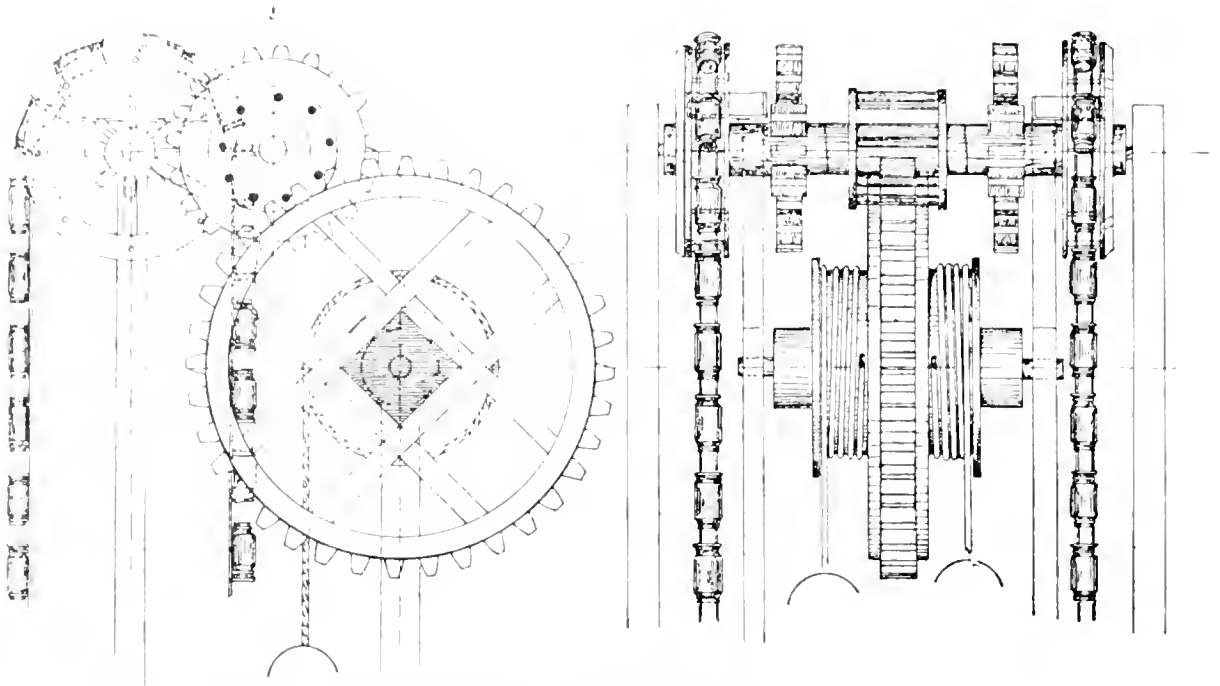


Figure 15.— ISLAMIC PUMP POWERED BY A WEIGHT DRIVE, after the text cited in figure 14.

The devices include a many chambered wheel (see fig. 14) similar to the Alfonsine mercury "escapement," a wheel of slanting tubes constructed like the noria (see fig. 15), wheels of weights swinging on arms as described by Villard of Honnecourt, and a remarkable device which seems to be the earliest known example of a weight drive. This latter machine is a pump, in which a chain of buckets is used to raise water by passing over a pulley which is geared to a drum powered by a falling weight (see fig. 16); perhaps for balance, the whole arrangement is made in duplicate with common axes for the corresponding parts.

The Islamic tradition of water clocks did not involve the use of gears, though very occasionally a pair is used to turn power through an angle when this is dictated by the use of a water wheel in the automata. In the main, everything is worked by floats and strings or by hydraulic or pneumatic forces, as in Heron devices. The automata are very elaborate, with figures of men, monkeys, peacocks, etc., symbolizing the passage of hours.

MEDIEVAL EUROPE

Things from nearly all the developments already noted from other parts of the world are found to occur in medieval Europe, often coming through

channels of communication more precisely determinable than those hitherto mentioned. Before the influx of Islamic learning at the time of transmission of the Toledo Tables (12th century) and the Alfonsine Tables (which reached Paris *ca.* 1292), there are occasional references to the most primitive mechanized "visual aids" in astronomy.

The most famous of these occurs in an historical account by Richer of Rheims about his teacher Gerbert (born 946, later Pope Sylvester II, 990-1003). Several instruments made by Gerbert are described in detail; he includes a fine celestial globe made of wood covered with horsehide and having the stars and lines painted in color, and an armillary sphere having sighting tubes similar to those always found on Chinese instruments but never on the Ptolemaic variety. Lastly, he cites "the construction of a sphere, most suitable for recognizing the planets," but unfortunately it is not clear from the description whether or not the model planets were actually to be animated mechanically. The text runs:²⁷

Within this oblique circle (the zodiac on the ecliptic of the globe) he hung the circles of the wandering stars (the planets) with marvellous ingenuity, whose orbits, heights

²⁷ Once more I am indebted to Professor Loren MacKinney and Miss Harriet Lattin (see footnote 11) for making their collections on Gerbert available to me.

and even the distance from each other he demonstrated to his pupils most effectually. Just how he accomplished this it is unsuitable to enter into here because of its extent lest we should appear to be wandering from our main theme.

Thus, although there is a hint of mechanical complexity, there is really no justification for such an assumption; the description might well imply only a zodiac band on which the orbits of the planets were painted. On the other hand it is not inconceivable that Gerbert could have learned something of Islamic and other extra-European traditions during his period of study with the Bishop of Barcelona—a traveling scholarship that seems to have had many repercussions on the whole field of European scholarship.

Once the floodgates of Arabic learning were opened, a stream of mechanized astronomical models poured into Europe. Astrolabes and equatoria rapidly became very popular, mainly through the reason for which they had been first devised, the avoidance of tedious written computation. Many medieval astrolabes have survived, and at least three medieval equatoria are known. Chaucer is well known for his treatise on the astrolabe; a manuscript in Cambridge, containing a companion treatise on the equatorium, has been tentatively suggested by the present author as also being the work of Chaucer and the only piece written in his own hand.

The geared astrolabe of al-Biruni is another type of protoclock to have been transmitted. A specimen in the Science Museum, London,²⁸ though unfortunately now incomplete, has a very sophisticated arrangement of gears for moving pointers to indicate the correct relative positions and movements of the sun and moon (see figs. 17 and 18). Like the earlier Muslim example it contains wheels with odd numbers of gear teeth (14, 27, 39); however, the teeth are no longer equilateral in shape, but approximate a more modern slightly rounded form. This example is French and appears to date from *ca.* 1300. Another Gothic astrolabe with a similar gear ring on the rete, said to date from *ca.* 1400 (it could well be much earlier) is now in the Billmeier collection (London).²⁹

Turning from the mechanized astrolabe to the mechanized equatorium, we find the work of Richard of Wallingford (1292?–1336) of the greatest interest

as providing an immediate precursor to that of de Dondi. He was the son of an ingenious blacksmith, making his way to Merton College, Oxford, then the most active and original school of astronomy in Europe, and winning later distinction as Abbot of St. Albans. A text by him, dated 1326–27, described in detail the construction of a great equatorium, more exact and much more elaborate than any that had gone before.³⁰ Nevertheless it is evidently a normal manually operated device like all the others. In addition to this instrument, Richard is said to have constructed *ca.* 1320, a fine planetary clock for his Abbey.³¹ Bale, who seems to have seen it, regarded it as without rival in Europe, and the greatest curiosity of his time. Unfortunately, the issue was confused by Leland, who identified it as the Albion (*i.e.*, all-by-one), the name Richard gives to his manual equatorium. This clock was indeed so complex that Edward III censured the Abbot for spending so much money on it, but Richard replied that after his death nobody would be able to make such a thing again. He is said to have left a text describing the construction of this clock, but the absence of such a work has led many modern writers to support Leland's identification and suppose that the device was not a mechanical clock.

A corrective for this view is to be had from a St. Albans manuscript (now at Gonville and Caius College, Cambridge) that described the methods for setting out toothed wheels for an astronomical horologium designed to show the motions of the planets. Although the manuscript copy is to be dated *ca.* 1330, it clearly indicates that a geared planetary device was known in St. Albans at an early date, and it is reasonable to suppose that this was in fact the machine made by Richard of Wallingford. Unfortunately the text does not appear to give any relevant information about the presence of an escapement or any other regulatory device, nor does it mention the source of power.³² Now a geared version of the

²⁸ The Latin text of the treatise on the Albion, has been transcribed by Rev. H. Salter and published in R. L. Gunther, *Early watches in Oxford*, Oxford, 1928, vol. 2, pp. 349–370. An analysis of its design is given in Price, *op. cit.* (footnote 22), pp. 127–130.

²⁹ Such evidence as there is for the existence and form of the clock is collected by Gunther, *op. cit.* (footnote 30), p. 42.

³² I have discussed this new manuscript source in "Two medieval texts on astronomical clocks," *Technique, History*, 3, 1956, vol. 1, no. 10, p. 156. The manuscript in question is ms. 230.116, Gonville and Caius College, Cambridge, folios 115–119, pp. 31–36.

²⁸ Item 198 in Gunther, *op. cit.* (footnote 21). I am grateful to the authorities of that museum for permission to reproduce photographs of this instrument.

²⁹ Sotheby and Co., London, sale of March 14, 1957, lot 154. The outer rim of the rete has 120 teeth.

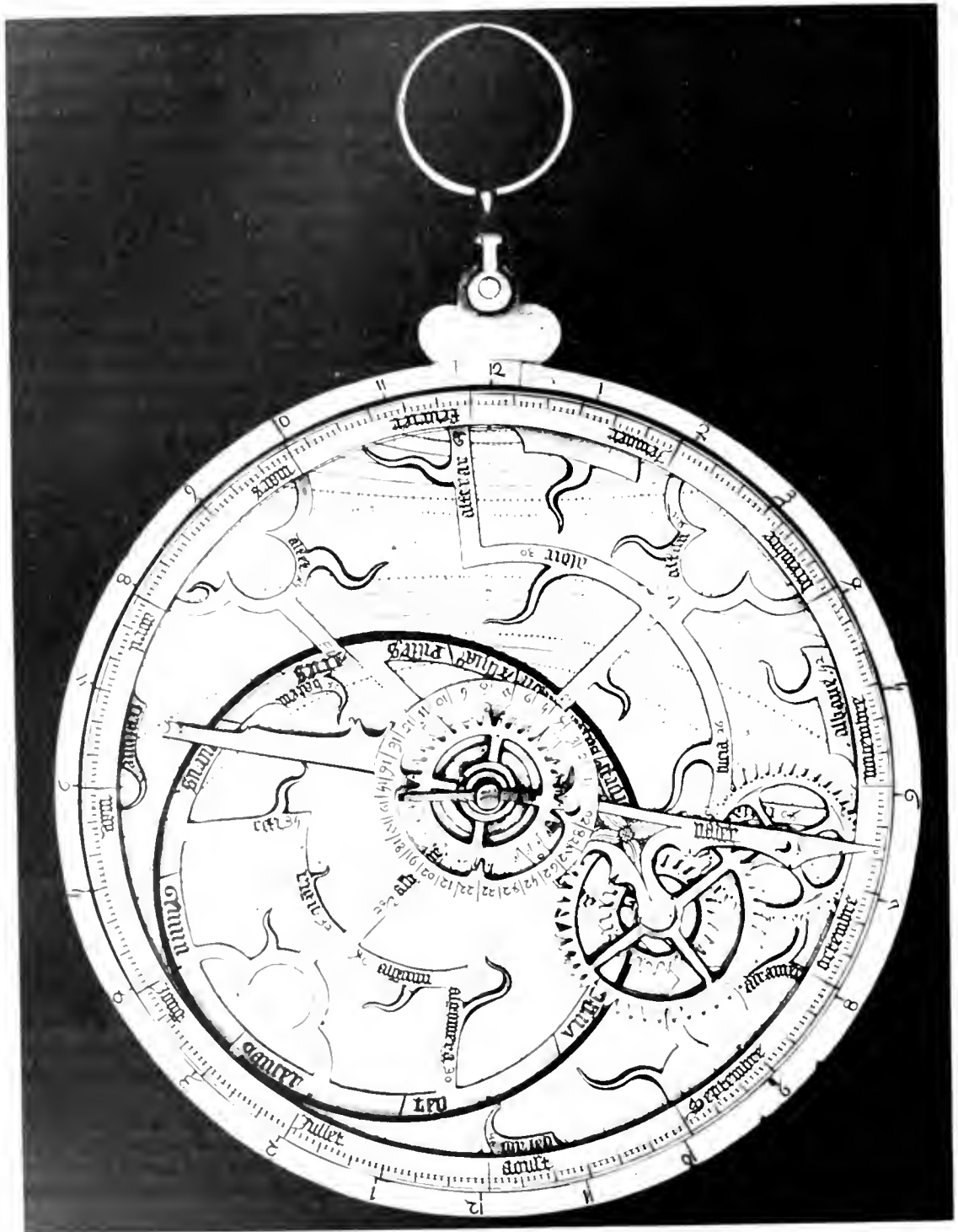


Figure 17. FRENCH GEARED ASTROLABE OF TREFOIL GOTHIC DESIGN, ca. A. D. 1300. The gearing on the pointer is, from the center: $(32)/14-45+27-39$, the last meshing with a concave annular gear of 180 teeth around the rim of the rete of the astrolabe. A second pointer, geared to this so as to follow the Moon, seems to be lacking. (Photo courtesy of Science Museum, London.)

Albion would appear to correspond very closely indeed to the dial-work which forms the greater part of the de Dondi clock, and for this reason we suggest now that the two clocks were very closely related in other ways too. This, circumstantial though it be, is evidence for thinking that the weight drive and some form of escapement were known to Richard of Wallingford, *ca.* 1320. It would narrow the gap between the clock and the protoclocks to less than half a century, perhaps a single generation, in the interval *ca.* 1285–1320. In this connection it may be of interest that Richard of Wallingford knew only the Toledo tables corpus, that of the Alfonsine school did not arrive in England until after his death.

There are, of course, many literary references to the waterlocks in medieval literature. In fact most of these are from quotations which have often been produced erroneously in the history of the mechanical

It seems probable that some of these water clocks could have been simple drip clepsydras, with perhaps a striking arrangement added. A most fortunate discovery by Drover has now brought to light a manuscript illumination that shows that these water clocks, at least by *ca.* 1285, had become more complex and were rather similar in appearance to the Alfonsine mercury drum.³⁴ The illustration (fig. 19) is from a moralized Bible written in northern France, and accompanies the passage where King Hezekiah is given a sign by the Lord, the sun being moved back ten steps of the clock. The picture clearly shows the central water wheel and below it a dog's head spout gushing water into a bucket supported by chains, with a (weight ?) cord running behind. Above the wheel is a carillon of bells, and to one side a rosette which might be a fly or a model sun. The wheel appears to have 15 compartments, each with a cen-

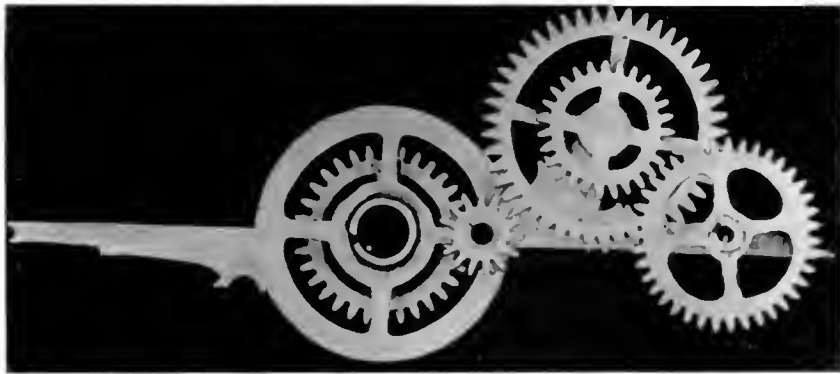


Figure 18.—GEAR TRAIN OF POINTER in figure 17. (Photo courtesy of Science Museum, London.)

clock, thereby providing many misleading starts for that history, as noted previously in the discussion of the horologium. There are however enough mentions to make it certain that water clocks of some sort were in use, especially for ecclesiastic purposes, from the end of the 12th century onwards. Thus, Jocelin of Brakelond tells of a fire in the Abbey Church of Bury St. Edmunds in the year 1198.³³ The relics would have been destroyed during the night, but just at the crucial moment the clock bell sounded for matins and the master of the vestry sounded the alarm. On this “the young men amongst us ran to get water, some to the well and others to the clock” probably the sole occasion on which a clock served as a fire hydrant.

tral hole (perhaps similar to that in the Alfonsine clock) and it is supported on a square axle by a bracket, the axle being wedged in the traditional fashion. The projections at the edge of the wheel might be gear teeth, but more likely they are used only for tripping the striking mechanism. If it were not for the running water spout it would be very close to the Alfonsine model; but with this evidence it seems impossible to arrive at a clear mechanical interpretation.

³⁴ C. B. Drover, “A medieval monastic water-clock,” *Antiquarian Horology*, 1954, vol. 1, no. 5, pp. 54–58, 63. Because this water clock uses wheels and strikes bells one must reject the evidence of literary reference, such as by Dante, from which the mention of wheels and bells have been taken as positive proof of the existence of mechanical clocks with mechanical escapements. The to-and-fro motion of the mechanical clock escapement is quite an impressive feature, but there seems to be no literary reference to it before the time of de Dondi.

³³ *The Chronicle of Jocelin of Brakelond . . .*, H. E. Butler (ed.), London, 1949, p. 106.

From the adjacent region there is another account of a striking water clock, the evidence being inscriptions on slates, discovered in Villers Abbey near Brussels;³⁵ these may be closely dated as 1267 or 1268 and provide the remains of a memorandum for the sacrist and his assistants in charge of the clock.

Always set the clock, however long you may delay on [the letter "A"] afterwards you shall pour water from the little pot (pottulo) that is there, into the reservoir (cacabum) until it reaches the prescribed level, and you must do the same when you set [the clock] after compline so that you may sleep soundly.

A quite different sort of evidence is to be had from the writings of Robertus Anglicus in 1271 where one gets the impression that just at this time there was active interest in the attempt to make a weight-driven anaphoric clock and to regulate its motion by some unstated method so that it would keep time with the diurnal rotation of the heavens:³⁶

Nor is it possible for any clock to follow the judgment of astronomy with complete accuracy. Yet clockmakers (artifices horologiorum) are trying to make a wheel (circulum) which will make one complete revolution for every one of the equinoctial circle, but they cannot quite perfect their work. But if they could, it would be a really accurate clock (horologium verax valde) and worth more than an astrolabe or other astronomical instrument for reckoning the hours, if one knew how to do this according to the method aforesaid. The method of making such a clock would be this, that a man make a disc (circulum) of uniform weight in every part so far as could possibly be done. Then a lead weight should be hung from the axis of that wheel (axi ipsius rote) and this weight would move that wheel so that it would complete one revolution from sunrise to sunrise, minus as much time as about one degree rises according to an approximately correct estimate. For from sunrise to sunrise, the whole equinoctial rises, and about one degree more, through which degree the sun moves against the motion of the firmament in the course of a

³⁵ *Annales de la Société Royale d'Archéologie de Bruxelles*, 1896, vol. 18, pp. 203-215, 404-451. The translation here is cited from Drover, *op. cit.* (footnote 34), p. 56.

³⁶ L. Thorndike, *The Sphere of Sacrobosco and its commentators*, Chicago, 1949, pp. 180, 230.



Figure 19. MANUSCRIPT ILLUMINATION OF A MEDIEVAL WATERCLOCK, showing a partitioned wheel, a weight drive, and a carillon for striking. From Drover (see footnote 34).

natural day. Moreover, this could be done more accurately if an astrolabe were constructed with a network on which the entire equinoctial circle was divided up.

The text then continues with technical astronomical details of the slight difference between the rate of rotation of the sun and of the fixed stars (because of the annual rotation of the sun amongst the stars) but it gives no indication of any regulatory device. Again it should be noted, this source comes from France; Robertus, though of English origin, apparently being then a lecturer either at the University of Paris or at that of Montpellier. The date of this passage, 1271, has been taken as a *terminus post quem* for the invention of the mechanical clock. In the next section we shall describe the text of Peter Peregrinus, very close to this in place and date, which describes just such a machine, conflating it with accounts of an armillary sphere, perpetual motion, and the magnetic compass—so bringing all these threads together for the first time in Europe.

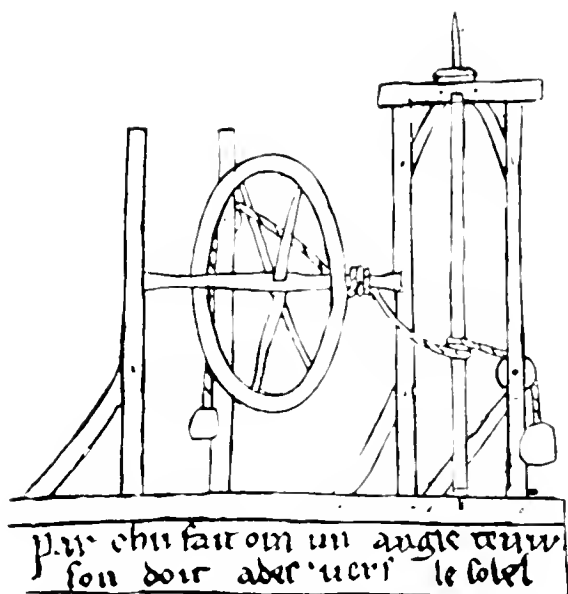


Figure 20. ARRANGEMENT FOR TURNING A FIGURE OF AN ANGEL. It has been alleged that this drawing by Villard represents an escapement. After Lassus (see footnote 37).

We have reserved to the last one section of evidence which may or may not be misleading, the famous notebook of Villard (Wilars) of Honnecourt, near Cambrai. The album, attributed to the period 1240–1251, contains many drawings with short annotations, three of which are of special interest to our investigations.³⁷ These comprise a steeplelike structure labeled “cest li masons don orloge” (this is the house of a clock), a device including a rope, wheel and axle (fig. 20), marked “par chu fait on un angle tenir son doit aders vers le solel” (by this means an angel is made to keep his finger directed towards the sun), and a perpetual motion wheel which we shall reserve for later discussion.

The clock tower, according to Drexler, shows no place for a dial but suggests the use of bells because of its open structure, suitable for letting out the sound. Moreover, he suggests that the delicacy of the line indicates that it was not really a full-size steeple but rather a small towerlike structure standing

³⁷ The album was published with facsimiles by J. B. A. Lassus, 1858. An English edition with facsimiles of 33 of the 41 folios was published by Rev. Robert Willis, Oxford, 1859. An extensive summary of this section is given, with illustrations, by J. Drummond Robertson, *The evolution of clockwork*, London, 1931, pp. 14–15.

only a few feet high within the church. There is, alas, nothing to tell us about the clock it was intended to house; most probably it was a water clock similar to that of the illustrated Bible of ca. 1285.

The drawing of the rope, wheel and axle, for turning an angel to point towards the sun can have a simple explanation or a more complicated one. If taken at its face value the wheel on its horizontal axis acts as a windlass connected by the counterpoised rope to the vertical shaft which it turns, thereby moving (by hand) the figure of an angel (not shown) fixed to the top of this latter shaft. Such an explanation was in fact suggested by M. Quicherat,³⁸ who first called attention to the Villard album and pointed out that a leaden angel existed in Chartres before the fire there in 1836. It is a view also supported from another drawing in the album which describes an eagle whose head is made to turn towards the deacon when he reads the Gospel. Slight pressure on the tail of the bird causes a similar rope mechanism to operate.

A quite different interpretation has been suggested by Frémont;³⁹ he believes that the wheel may have acted as a fly-wheel and the ropes and counterpoises,

³⁸ M. Jules Quicherat, *Revue Archéologique*, 1849, vol. 6.
³⁹ M. C. Frémont, *Origine de l'horloge à poids*, Paris, 1915.

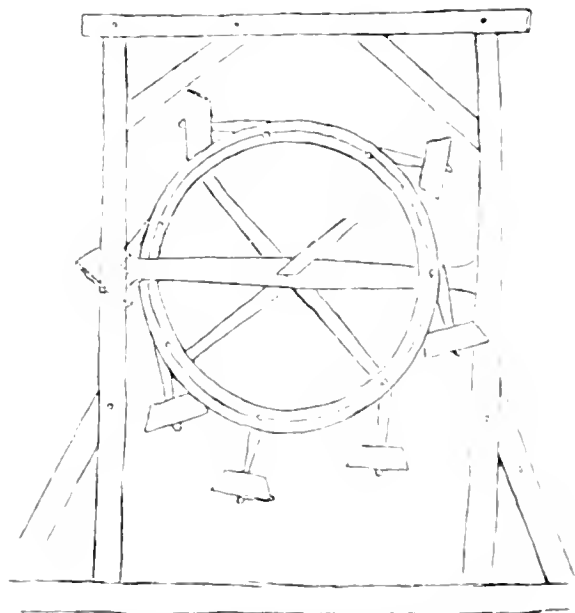


Figure 21. VILLARD'S PERPETUAL MOTION WHEEL, from Lassus (see footnote 37).

turning first one way then the other acted as a sort of mechanical escapement. Such an arrangement is however mechanically impossible without some complicated free-wheeling device between the drive and the escapement, and its only effect would be to oscillate the angel rapidly rather than turn it steadily. I believe that Fréumont, over-anxious to provide a proto-escapement, has done too much violence to the facts and turned away without good reason from the more simple and reasonable explanation. It is nevertheless still possible to adopt this simple interpretation and yet to have the system as part of a clock. If the left-hand counterpoise, conveniently raised higher than that on the right, is considered as a float fitting into a clepsydra jar, instead of as a simple weight, one would have a very suitable automatic system for turning the angel. On this explanation, the purpose of the wheel would be merely to provide the manual adjustment necessary to set the angel from time to time, compensating for irremediable inaccuracies of the clepsydra.

Having discussed the Villard drawings which are already cited in horological literature, we must draw attention to the fact that this medieval architect also gives an illustration of a perpetual motion wheel. In this case (fig. 21) it is of the type having weights at the end of swinging arms, a type that occurs very frequently at later dates in Europe and is also given in the Islamic texts. We cannot, in this case, suggest that drawings of clocks and of perpetual motion devices occur together by more than a coincidence, for Villard seems to have been interested in most sorts of mechanical device. But even this type of coincidence becomes somewhat striking when repeated often enough. It seems that each early mention of "self-moving wheels" occurs in connection with some sort of clock or mechanized astronomical device.

Having now completed a survey of the traditions of astronomical models, we have seen that many types of device embodying features later found in mechanical clocks evolved through various cultures and flowed into Europe, coming together in a burst of multifarious activity during the second half of the 13th century, notably in the region of France. We must now attempt to fill the residual gap, and in so doing examine the importance of perpetual motion devices, mechanical and magnetic, in the crucial transition from protoclock to mechanical-escapement clock.

Perpetual Motion and the Clock before de Dondi

We have already noted, more or less briefly, several instances of the use of wheels "moving by themselves" or the use of a fluid for purposes other than as a motive power. Chronologically arranged, these are the Indian devices of *ca.* 1150 or a little earlier, as those of Riḍwān *ca.* 1200, that of the Alfonsine mercury clock, *ca.* 1272, and the French Bible illumination of *ca.* 1285. This strongly suggests a steady transmission from East to West, and on the basis of it, we now tentatively propose an additional step, a transmission from China to India and perhaps further West, *ca.* 1100, and possibly reinforced by further transmissions at later dates.

One need only assume the existence of vague traveler's tales about the existence of the 11th-century Chinese clocks with their astronomical models and jackwork and with their great wheel, apparently moving by itself but using water having no external inlet or outlet. Such a stimulus, acting as it did on a later occasion when Galileo received word of the invention of the telescope in the Low Countries, might easily lead to the re-invention of just such perpetual-motion wheels as we have already noted. In many ways, once the idea has been suggested it is natural to associate such a perpetual motion with the incessant diurnal rotation of the heavens. Without some such stimulus however it is difficult to explain why this association did not occur earlier, and why, once it comes there seems to be such a chronological procession from culture to culture.

We now turn to what is undoubtedly the most curious part of this story, in which automatically moving astronomical models and perpetual motion wheels are linked with the earliest texts on magnetism and the magnetic compass, another subject with a singularly troubled historical origin. The key text in this is the famous *Epistle on the magnet*, written by Peter Peregrinus, a Picard, in an army camp at the Siege of Lucera and dated August 8, 1269.⁴⁰ In spite of the precise dating it is certain that the work was done long before, for it is quoted unmistakably by Roger Bacon in at least three places, one of which must have been written before *ca.* 1250.⁴¹

⁴⁰ For this, I have used and quoted from the very beautiful edition in English, prepared by Silvanus P. Thompson, London, Chiswick Press, 1902.

⁴¹ See E. G. R. Taylor, "The South-pointing needle," *Imago Mundi*, Leiden, 1951, vol. 8, pp. 1-7 (especially pp. 1, 2).

The *Epistle* contains two parts: in the first there is a general account of magnetism and the properties of the loadstone, closing with a discussion “of the inquiry whence the magnet receives the natural virtue which it has.” Peter attributed this virtue to a sympathy with the heavens, proposing to prove his point by the construction of a “terrella,” a uniform sphere of loadstone which is to be carefully balanced and mounted in the manner of an armillary sphere, with its axis directed along the polar axis of the diurnal rotation. He then continues:

Now if the stone then move according to the motion of the heavens, rejoice that you have arrived at a secret marvel. But if not, let it be ascribed rather to your own want of skill than to a defect of Nature. But in this position, or mode of placing, I deem the virtues of this stone to be properly conserved, and I believe that in other positions or parts of the sky its virtue is dulled, rather than preserved. By means of this instrument at all events you will be relieved from every kind of clock (horologium), for by it you will be able to know the Ascendant at whatever hour you will, and all other dispositions of the heavens which Astrologers seek after.

It should be noted that the device is to be mounted like an astronomical instrument and used like one, rather than as a time teller, or as a simple demonstration of magnetism. In the second part of the *Epistle* Peter turns to practical instruments, describing for the first time, the construction of a magnetic compass consisting of a loadstone or iron needle pivoted with a casing marked with a scale of degrees. The third chapter of this section, concluding the *Epistle*, then continues with the description of a perpetual motion wheel, “elaboured with marvellous ingenuity, in the pursuit of which invention I have seen many people wandering about, and wearied with manifold toil. For they did not observe that they could arrive at the mastery of this by means of the virtue, or power of this stone.”

This tells us incidentally, that the perpetual motion device was a subject of considerable interest at this

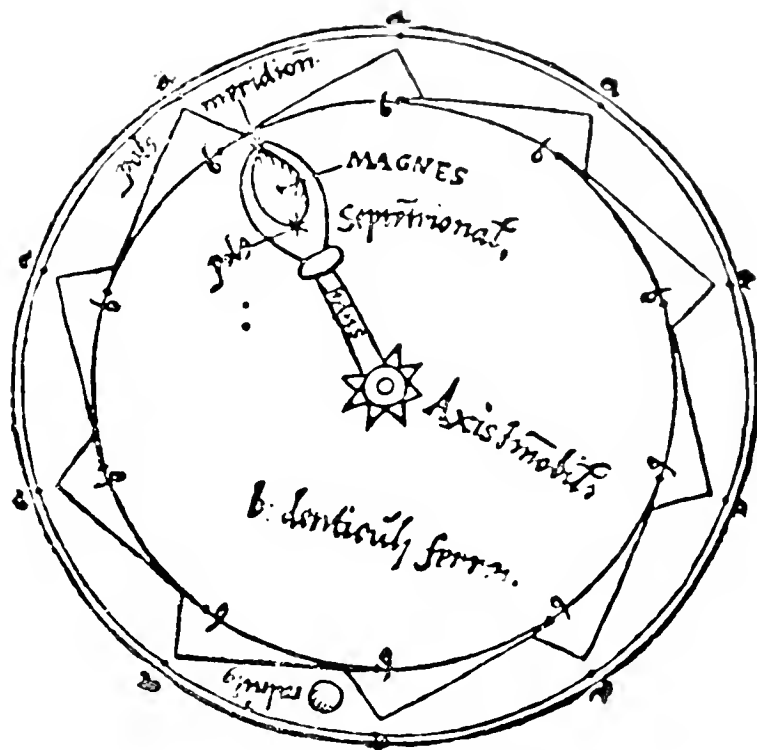


Figure 22. MAGNETIC PERPETUAL MOTION WHEEL illustrated by Peter Peregrinus; from the edition of S. P. Thompson (see footnote 40).

time.⁴² Oddly enough, Peter does not now develop his idea of the *terrella*, but proceeds to something quite new, a device (see fig. 22) in which a bar-magnet loadstone is to be set towards the end of a pivoted radial arm with a circle fitted on the inside with iron “gear teeth,” the teeth being there not to mesh with others but to draw the magnet from one to the next, a little bead providing a counterweight to help the inertia of rotation carry the magnet from one point of attraction to the next. It is by no means the sort of device that one would naturally evolve as a means of making magnetism work perpetually, and I suggest that the toothed wheel is another instance of some vague idea of proto-clocks, perhaps that of Su Sung, being transmitted from the East.

The work of Peter Peregrinus is cited by Roger Bacon in his *De secretis* as well as in the *Opus majus*

⁴² I have wondered whether the medieval interest in perpetual motion could be connected with the use of the “Wheel of Fortune” in churches as a substitute for bell-ringing on Good Friday. Unfortunately I can find no evidence for or against the conjecture.

and *Opus minus*. In the first and earliest of these occurs a description, taken from Ptolemy, of the construction of the (observing) armillary sphere. He says that this cannot be made to move naturally by any mathematical device, but "a faithful and magnificent experimenter is straining to make one out of such material, and by such a device, that it will revolve naturally with the diurnal heavenly rotation." He continues with the statement that this possibility is also suggested by the fact that the motions of comets, of tides, and of certain planets also follow that of the Sun and of the heavens. Only in the *Opus minus*, where he repeats reference to this device, does he finally reveal that it is to be made to work by means of the loadstone.

The form of Bacon's reference to Peregrinus is strongly reminiscent of the statement by Robertus Anglicus, already mentioned as an indication of preoccupation with diurnally rotating wheels, at a date (1271) remarkably close to that of the *Epistle* (1269) — so much so that it could well be thought that the friend to which Peter was writing was either Robert himself or somebody associated with him, perhaps at the University of Paris — a natural place to which the itinerant Peter might communicate his findings.

The fundamental question here, of course, is whether the idea of an automatic astronomical device was transmitted from Arabic, Indian, or Chinese sources, or whether it arose quite independently in this case as a natural concomitant of identifying the poles of the magnet with the poles of the heavens. We shall now attempt to show that the history of the magnetic compass might provide a quite independent argument in favour of the hypothesis that there was a 'stimulus' transmission.

The Magnetic Compass as a Fellow-traveler from China

The elusive history of the magnetic compass has many points in common with that of the mechanical clock. Just as we have astronomical models from the earliest times, so we find knowledge of the loadstone and some of its properties. Then, parallel to the development of protoclocks in China throughout the middle ages, we have the evidence analyzed by Needham, showing the use of the magnet as a divination device and of the (nonmagnetic) south-pointing chariot, which has been confusedly allied to the compass. Curiously, and perhaps significantly the

Chinese history comes to a head at just the same time for compasses and clocks, and a prime authority for the Chinese compass is Shen Kua (1030-1093) who also appears in connection with the clock of Su Sung, and who wrote about the mechanized armillary spheres and other models *ca.* 1086.

Another similarity occurs in connection with the history of the compass in medieval Europe. The treatise of Peter Peregrinus, already discussed, provides the first complete account of the magnetic compass with a pivoted needle and a circular scale, and this, as we have seen, may be connected with protoclocks and perpetual-motion devices. There are several earlier references, however, to the use of the directive properties of loadstone, mainly for use in navigation, but these earliest texts have a long history of erroneous interpretation which is only recently being cleared away. We know now that the famous passages in the *De naturis rerum* and *De utensilibus* of Alexander Neckham⁴³ (*ca.* 1187) and a text by Hugues de Berze⁴⁴ (after *ca.* 1204) refer to nothing more than a floating magnet without pivot or scale, but using a pointer at right angles to the magnet, so that it pointed to the east, rather than the north or south. A similar method is described (*ca.* 1200) in a poem by Guyot de Provins, and in a history of Jerusalem by Jacques de Vitry (1215).⁴⁵ It is of the greatest interest that, once more, all the evidence seems to be concentrated in France (Neckham was teaching in Paris) though at an earlier period than that for the protoclocks.

The date might suggest the time of the first great wave of transmissal of learning from Islam, but it is clear that in this instance, peculiar for that reason, that Islam learned of the magnetic compass only after it was already known in the West. In the earliest Persian record, some anecdotes compiled by al-'Awfī *ca.* 1230,⁴⁶ the instrument used by the captain during a storm at sea has the form of a piece of hollow iron, shaped like a fish and made to float on the water after magnetization by rubbing with a

⁴³ W. E. May, "Alexander Neckham and the pivoted compass needle," *Journal of the Institute of Navigation*, 1955, vol. 8, no. 3, pp. 283-284.

⁴⁴ W. E. May, "Hugues de Berze and the mariner's compass," *The Mariner's Mirror*, 1953, vol. 39, no. 2, pp. 103-106.

⁴⁵ H. Balmer, *Beiträge zur Geschichte der Erkenntnis des Erdmagnetismus*, Aarau, 1956, p. 52.

⁴⁶ The collection is the *Gamū 'al Hikajat*; the relevant passage being given in German translation in Balmer, *op. cit.* (footnote 45), p. 54.

Chronological Chart

CLASSICAL EUROPE

- 3rd C., B.C. Archimedes planetarium
- 2nd C., B.C. Hipparchus Stereographic Projection
- 1st C., B.C. Vitruvius odometer and water clocks
- 65, B.C. (ca.) Antikythera machine
- 1st C., A.D. Hero odometer and water clocks
- 2nd C., A.D. Salzburg and Vosges anaphoric clocks

ISLAM

- 807 Harun-al-Rashid
- 850 (ca.) Earliest extant astrolabes
- 1000 Geared astrolabe of al-Biruni
- 1025 Equatorium text

EUROPE

- 1000 Gerbert astronomical model
- 1150 Saladin clock
- 1200 (ca.) Riḍwān water-clocks, perpetual motion and weight drive
- 1206 al-Jazari clocks, etc.
- 1221 Geared astrolabe
- 1232 Charlemagne clock
- 1243 al-Kompas (compass)
- 1272 Alfonsine corpus clock with mercury drum, equatoria
- 1245 Villard clocktower, "escapement," perpetual motion
- 1267 Villers-Abbay clock
- 1266 Peregrinus, compass and perpetual motion
- 1271 Robertus Anglicus, animated models and "perpetual motion" clock
- 1285 Drover's water clock with wheel and weight drive
- 1300 (ca.) French geared astrolabe
- 1320 Richard of Wallingford astronomical clock and equatorium
- 1304 de Dondi's astronomical clock with mechanical escapement
- later 14th C. Tradition of escapement clocks continues and degenerates into simple time-keepers

CHINA

- 4th C., B.C. Power gear
- 2nd C., A.D. Chang Hên, animated globe, odometer
- Continuing tradition of animated astronomical models
- 725 Invention of Chinese escapement by I-Hsing and Liang Ling-tsan
- 1074 Shen Kua, clocks and magnetic compass
- 1086 Su Sung clock built
- 1101 Su Sung clock destroyed

INDIA

- 1100 (ca.) Sūrya Siddhānta animated astronomical models and perpetual motion
- 1170 (ca.) Siddhānta Siromani animated models and perpetual motion

loadstone; the fishlike form is very significant, for this is distinctly Chinese practice. In a second Muslim reference, that of Baiḥak al-Qabājiqī (*ca.* 1282), the ordinary wet-compass is termed “al-kombas,” another indication that it was foreign to that language and culture.⁴⁷

There is therefore reasonable grounds for supporting the medieval European tradition that the magnetic compass had first come from China, though one cannot well admit that the first news of it was brought, as the legend states, by Marco Polo, when he returned home in 1260. There might well have been another wave of interest, giving the impetus to Peter Peregrinus at this time, but an earlier transmission, perhaps along the silk road or by travelers in crusades, must be postulated to account for the evidence in Europe, *ca.* 1200. The earlier influx does not play any great part in our main story; it arrived in Europe before the transmission of astronomy from Islam had got under way sufficiently to make proto-clocks a

subject of interest. For a second transmission, we have already seen how the relevant texts seem to cluster, in France *ca.* 1270, around a complex in which the proto-clocks seem combined with the ideas of perpetual motion wheels and with new information about the magnetic compass.

The point of this paper is that such a complex exists, cutting across the histories of the clock, the various types of astronomical machines, and the magnetic compass, and including the origin of “self-moving wheels.” It seems to trace a path extending from China, through India and through Eastern and Western Islam, ending in Europe in the Middle Ages. This path is not a simple one, for the various elements make their appearances in different combinations from place to place, sometimes one may be dominant, sometimes another may be absent. Only by treating it as a whole has it been possible to produce the threads of continuity which will, I hope, make further research possible, circumventing the blind alleys found in the past and leading eventually to a complete understanding of the first complicated scientific machines.

⁴⁷ Balmer, *op. cit.* (footnote 45), p. 53.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 7

MINE PUMPING IN
AGRICOLA'S TIME AND LATER

Robert P. Muthauf

MINE PUMPING IN AGRICOLA'S TIME AND LATER

Coins are a source of information much used by historians. Elaborately detailed mining landscapes on 16th-century German coins in the National Museum, discovered by the curator of numismatics and brought to the author's attention, led to this study of early mine-pumping devices.

THE AUTHOR: Robert P. Multbauſ is curator of Science and Technology, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.

THE HABIT of heavy reliance on a single source for the substance of the history of Medieval and Renaissance mining techniques in Europe has led to a rather drastic over-simplification of that history, a condition which persists tenaciously in the recent accounts of Parsons, Wolf, and Brouchead.¹ Our preoccupation with Agricola, who has been well known to the English-language public since the Hoovers' translation of 1912, seems to have inhibited the investigation of the development of the machines he describes so elegantly. More seriously, the opinion that mining techniques remained essentially the same for a century or two beyond his time appears to have hardened into a conviction.²

¹W. B. Parsons, *Engines and engineering in the Renaissance*, Baltimore, 1939. Abraham Wolf, *A history of science, technology, and philosophy in the 16th and 17th centuries*, New York, 1935; and *A history of science, technology and philosophy in the eighteenth century*, London, 1938. C. M. Brouchead, "Mining and quarrying to the seventeenth century," in Charles Singer and others, *A history of technology*, vol. 2, Oxford, 1956.

According to Parsons (*op. cit.*, footnote 1, p. 629) the introduction of machinery worked by animals and falling water, "radical improvements" of the 15th century, fixed the development of the art "until the eighteenth, and, in some respects, even well into the nineteenth century." Wolf in his *History of Science, Technology and Philosophy in the 16th Century* (p. 629, see footnote 1) writes that "apart from [the steam engine] mining remained almost the same during the 18th century" essentially similar to the methods described in Agricola's *De re metallica*. Brouchead (*op. cit.*, footnote 1, p. 236), in referring to the date 1673 also writes that "the principal change in methods of mining since Agricola's time occurred in the 17th century."

The history of the technology of mining, as distinguished from metallurgy, is largely a history of mechanization, and that mechanization has until the last century consisted principally in the development of what Agricola calls *tractinae*—hauling machines. That hauling machines of some complexity, Archimedian screws and a kind of noria, were used by the Romans for dewatering mines has been known for some time. Evidence of the survival of this technology beyond the fall of Rome remains to be found, and it is generally agreed that mining activity declined through the first millenium. The revival and extension of mining in the central European areas of German settlement is thought to have occurred from the 10th century, with an intensive development of the region known to Agricola (Erzgebirge) in the 13th century.³

This revival appears to have paralleled in general the political and cultural revival, but, as in any mining region, the exhaustion of easily workable surface deposits marked a critical point, when the necessity of deeper mining led to the construction of supported tunnels and the introduction of machinery for removing ores and water from deep mines. On the basis of revisions of capital structure and mining law which he regards as inspired by the financial necessities of deep mining, Bechtel dates this develop-

³Parsons, *op. cit.* (footnote 1), p. 179. T. A. Rickard, *Man and metals*, New York, 1932, vol. 2, pp. 519-521.

MINE-PUMPING MACHINERY ILLUSTRATED BY BRUNSWICK MULTIPLE TAALERS

These large silver coins weighing up to 15 ounces were first issued in 1574 in Brunswick by Duke Julius (1568-1586) of the Welfenbuttel line. Their historical background is rather unusual and interesting.

In 1570 the Duke decided to increase the output of his silver mines in the Harz and arranged for the opening of three new mines. In order to insure the retention of a portion of this increased silver output under his control, the Duke decided to issue an entirely new kind of silver coin which he called "Loeser," meaning redeemer. These were larger than taler-size pieces, and were struck in denominations from 1 $\frac{1}{4}$ to 16 taalers. The Duke ordered that each of his subjects was to purchase one of these large coins, the size of the coin to be acquired depending on the individual's wealth. The owners were not allowed to use these pieces in everyday trade, but could pawn them in case of dire need. They were expected to produce them at any time upon demand. Thus a means of hoarding, a "treasure piece," was created, and the risk of draining the country's wealth through replacement of good, full-weight silver coins with imported base currency was to some extent limited. At the same time, the Duke had a considerable sum of money at his disposal in case of emergency.

Similar Loesers were issued up to 1633 by different rulers of Brunswick. Some of the later issues are commemorative in character and might have served for presentation purposes. The workmanship of the machine is exquisite. They portray personages real and ideal and ornate coats of arms, in addition to the elaborate mining landscapes shown here. The U.S. National Museum is fortunate in having a number of examples through the generosity of Mr. Paul A. Straub.

For calling my attention to these coins, and for other invaluable assistance, I am indebted to the former curator of the numismatic collections of the U.S. National Museum, the late Stuart Mosher, and to the present curator, Dr. A. Clair-Stefanelli.

Figure 1 shows an overshot waterwheel driving through Stangenkunstler pumps in three separate shafts, each covered by the typical conical shaft house. It is possible that these shaft houses also cover horse whims used to operate bucket hoists such as that shown in the lower center. A house with three chimneys in the background may be the smelter. The horse over whose head the Deity holds a wreath is a symbol of Lüneberg.

ment from the mid-14th century.⁴ The mid-14th century situation is confused by the occurrence of the Black Death, which reduced mining activity drastically, and the events of which Bechtel speaks have been put as much as a century later.⁵ In any case, the development of deep-mining methods had

⁴ Heinrich Bechtel, *Wirtschafts- und Sozialgeschichte des deutschen Spätmittelalters*, Munich, 1930, pp. 202-203. Bechtel calls this one of the most revolutionary industrial developments of the middle ages.

⁵ Rickard (*op. cit.*, footnote 3, pp. 547-554, 561) also speaks of a decline through the exhaustion of surface deposits, but dates the revival 1480-1570. He supports this conclusion by statistics on the leading mine at Rammelsberg, which was unproductive from the Black Death (1347) to 1450, and only slightly active before 1518.

clearly made considerable progress in nonferrous mines when the *De re metallica* was written, in 1550.

For a detailed description of the mechanical equipment of this era we are largely indebted to Agricola.

He classifies hauling machines into four types: the ordinary bucket windlass, the piston suction pump, the chain of dippers, and the rag and chain pump. Although the first three have been known in antiquity, and the last perhaps even long before Christ, Agricola



Figure 1. Brunswick Silver Multiple Taler of Duke Friedrich, 1677. U.S. National Museum, Paper 45, *Smithsonian Studies in History and Technology*, No. 13, p. 113, 114.

Agri. 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.



Figure 2. BRUNSWICK SILVER 1½ TALER, Ernst August, 1688. (U. S. National Museum, Paul A. Straub coll.; Smithsonian photo 43334 A.)

use in mining would appear to date from the mid-14th century or later. This is not an historical account, and one who attempts to compare it with others of contemporary or later times encounters a difficulty in his use of descriptive Latin names rather than the common German names used by most others. English and German editors have interpreted them as follows:⁷

Latin	English	German
bulga	water bucket	Wasserkubel, Kehrrad
orbiculis	suction pump	Pumpe
situlis	chain of dippers	Kannen (werke), Bulgenkunst ⁸
machina, quae pilis aquas hauriunt	rag and chain pump	Heinzenkunst, Taschenkunst ⁹

⁷ Based on a comparison of the following editions of Agricola, *De re metallica*: Froben, Basel, 1556 (in Latin; the first edition); *The Mining Magazine*, London, 1912 (English translation by H. C. and L. H. Hoover); VDI, Berlin, 1928 (German translation by Carl Schifflner).

⁸ The emergence of the term Kunst in German mining terminology is connected with the application of water power, especially to pumping (see Heinrich Veith, *Deutsches Bergwörterbuch*, Breslau, 1870, article "Kunst").

⁹ According to Veith (*op. cit.*, footnote 8, p. 306), B. Rössler, in his *Speculum metallurgiae politissimum* (Dresden, 1700, p. 41) says that the Taschenkunst (pocket-work) was used with a pipe, like the rag and chain pump, and the translator of the German (1928) edition of *De re metallica* also uses Heinzen and Taschen interchangeably. Calvör and others, however, seem to use Taschenkunst for the ordinary chain of dippers, which seems better suited to its literal meaning.

Figure 2 shows two shaft-houses covering pumps driven by Stangenkusten. The source of power, hidden by the curious "log cabin" at the right, was probably a water-wheel. I have not found evidence that the Stangenkunst was used to operate bucket hoists, as appears to be the case here. It will be noticed that the above and below ground portions of these illustrations do not correlate precisely. This coin, like the others, shows miners doing various things familiar from Agricola—divining, digging, carrying, and operating windlasses.

Figure 3 exhibits the principal advantage of the Stangenkunst, in its utilization to connect a waterwheel located in a valley stream to driven machinery on the mountain some distance above. The lute-playing girl

The resemblance of the German term for bag (Bulge) to the Latin term for bucket (bulga) instead of the Latin term for bag (canalis), and the presence of buckets (Kübeln), bags (Bulgen), pockets (Taschen), or cans (Kannen) as components of three of Agricola's four categories of hauling machines are reasons enough for the apparent superfluity of German names, if not for his decision to avoid the use of German names. But it should also be noted that the names sometimes refer to a pump and its prime mover considered as a single machine. Such



Figure 4. MEDAL, 1690, SHOWING ST. ANNA MINE, near Freiberg. (Photo courtesy of Städtisches Museum, Braunschweig.)

(Lautenspielerin) refers to the Lautental mine. A Stangenkunst (fig. 7) existed here as recently as 1930.

The mines shown in figures 1-3 are in the Hartz region.

Figures 4 and 5 show the St. Anna mine in the Erzgebirge, near Freiberg, as illustrated on a medal in the Brunswick museum. Prominent in figure 4 is an aqueduct, one function of which is to supply a waterwheel in the house below, which in turn delivers power through the Stangenkunst to two open shafts. The reverse (fig. 5), an unusually fine view of the inner workings of a mine, shows, above ground, a typical horse whim driving a bucket windlass. Below ground is shown a crank-driven piston pump typical of those driven by Stangenkunst. In this case, however, it is driven by an underground vertical treadmill.

is the case with the Kehrrad, a bucket windlass driven by a reversible waterwheel which Agricola describes as his largest hauling machine.¹⁰

¹⁰ Agricola, *op. cit.* (footnote 7), ed. Hoover, p. 199. His contemporary and fellow-townsmen Mathesius equates the Kehrrad to the Bulgenkunst (*Scripita*, p. 145, Nurnberg, 1571). According to Veith (*op. cit.*, footnote 8, p. 286), Sebastian Münster in his *Cosmographia* . . . (p. 381, Basel, 1558), had previously mentioned its use in the mines of Meissen; and its introduction has been put as early as 1500 by Otto Vogel ("Christopher Pohlenz und seine Beziehungen zum Harzer Bergbau," *Beiträge zur Geschichte der Technik und Industrie*, 1913, vol. 5, p. 324.)



Figure 3. BRUNSWICK SILVER 4 LATER, LATER, August, 1685. (U. S. National Museum, Paul A. Straub coll.; Smithsonian photo 43334 A.)

Agricola describes 23 hauling devices of these four types, the diversity resulting generally from the application of three types of prime movers, men, horses, and waterwheels, and in the endowment of each in turn with a mechanical advantage in the form of gearing.¹¹ Although he does not specify clearly the relative importance of the various pumps, the majority (15) use man as the prime mover. He speaks of the advantages of some, noting that the horse whim has a power two and a half times that of the man windlass, and emphasizing the even greater power available in flowing water "when a running stream can be diverted to a mine." The most powerful machine then in use for deep mines appears to have been the horse-powered rag and chain pump.

Such, then, were the important mining machines of this early period of deep mining, according to the leading authority. But did they continue, as has been claimed, to be the only important machines of the subsequent century? G. E. Lohmeyer,¹² writing a little over a half century after the publication of *De re metallica*, declared:

The old miners, alten Bergleute, had Hemtzen, Kerratt, Bulgenkunst, Laschen-kunst, Pumpen, with which one lifted water with cans on pulleys or with a treadmill; and

¹¹ Agricola, *op. cit.* (footnote 7), ed. Hoover, pp. 100-102.

¹² G. E. Lohmeyer, *Bericht über Bergbau*, 1619, n. p., p. 3.



Figure 5. REVERSE OF MEDAL shown in figure 4. (Photo courtesy of Städtisches Museum, Braunschweig.)

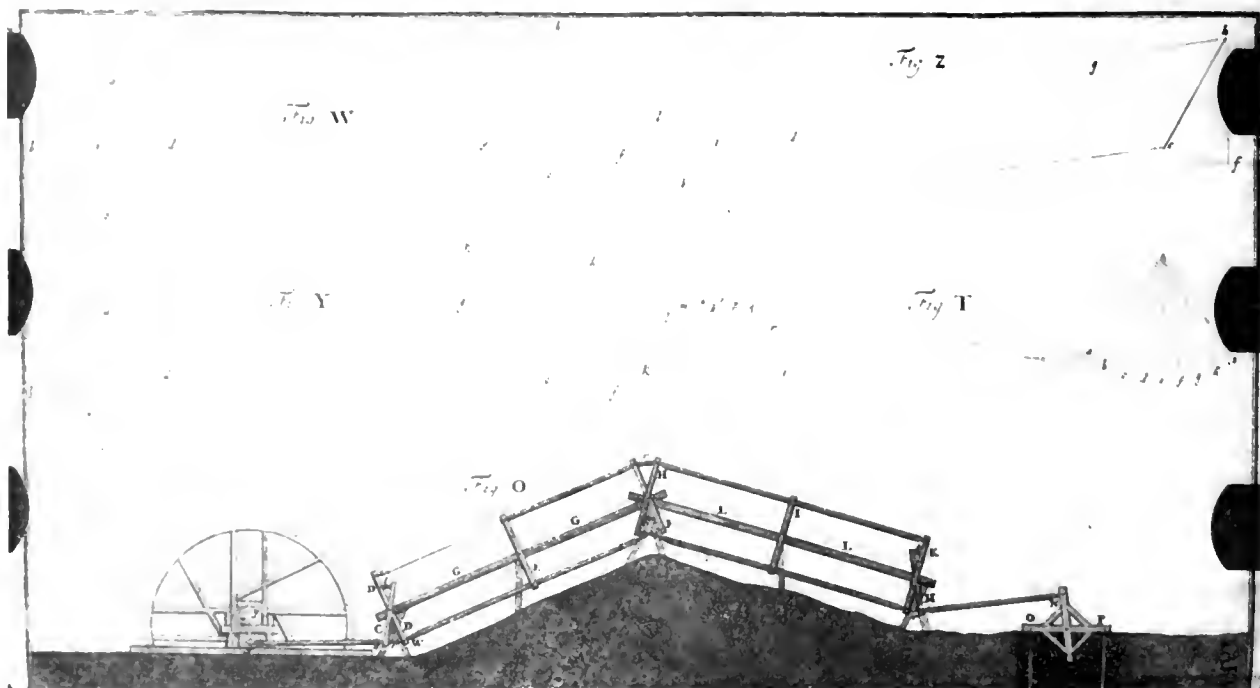


Figure 6. STANGENKUNST, SHOWING DRIVING WHEEL, FELDKUNST, AND KUNSTKREUZ. From H. Calvör (see footnote 15).

they devised and constructed these in which the poor people moved like cattle and wore themselves out. At that time they had powerful machines (Künste) using swift water, although it cost much to erect and maintain them, and was very dangerous since an iron chain of a Bulgenkunst alone often weighed 200 centner (over 10 tons) and more.

But today's artisan [jetzigen Künstler] far surpasses the old . . . since we have in the present time invented many other mining machines; such as the *Stangenkunst mit dem krummen Zapfen*, which raises water at small cost over 100 Lachter (562 feet).

The Stangenkunst, which can be roughly translated as "rod work with crank," was a piston pump driven through a crank and rods by a prime mover located at a distant point. Agricola describes a crank-driven piston pump, calling it a new machine invented ten years earlier.¹³ But it is not driven by

a distant prime mover. Like his other water-powered hauling machines it can only be used "when a running stream can be diverted to a mine." So far as we can determine from internal evidence, Agricola did not know the Stangenkunst.

Although the full development of the Stangenkunst came later, it was apparently introduced in Agricola's time. Its introduction to the Erzgebirge has been put as early as 1550.¹⁴ According to another authority it was introduced to the Harz in 1565 by one Heinrich Eschenbach of Meissen.¹⁵ Its significance is only made clear to us by later authorities. As shown in figure 3 it was adapted to the utilization of a distant stream, through the Feldstangen, an extended horizontal series of reciprocating rods, and the Kunstkreuz (fig. 6), a lever in the shape of a cross for changing at right angles the direction of power transmission. These improvements may have been almost contemporaneous with Agricola, as Calvör

¹³ Agricola, *Op. cit.* (footnote 7), ed. Hoover, pp. 184-185. The crank was centuries old at this time, and had been applied to pumping earlier than the time mentioned by Agricola, although perhaps not in mining. A drawing dated 1405 shows an Archimedian screw turned by a crank (Feldhaus, *Die Wasserkunst*, p. 834). The *Metallurgische Handbuch* of H. F. Bossert and W. F. Storck, Leipzig, 1912, Tafel 32), shows a similar arrangement.

¹⁴ Calvör, *Op. cit.* (footnote 13), p. 112. This arrangement was like that described by Agricola, although not in mining service.

¹⁵ O. Fritsche and A. Wagenbreth, "Die Wasserhaltungsmaschinen bei Agricola und sein Einfluss auf ihre weitere Entwicklung," in *Deutsche Akademie der Wissenschaft zu Berlin, Ges. des Agricola*, (East) Berlin: Akademie Verlag, 1953, p. 112.

¹⁶ Hennig Calvör, *Acta historico-chronologico-mechanica circa Metallurgiam . . .*, Braunschweig, 1763, pp. 36-37.

mentions the use of the *Feldkunst*, which term signified the extended rods, as having been known in 1565.

The disadvantage of moving the weight of a long extension of rods was obviated, during the 17th century, through the use of a double set of balanced rods, resembling a pantograph. At some later date the horse whim was fitted with a crank and adapted to the *Stangenkunst*,¹⁶ thus permitting the establishment of a veritable power network, as suggested in figure 1.

The Freiberg mine director Martin Planer reported in 1570 the installation since 1557 of thirty-eight "Kunsten und Zeugen" in mines under his charge. That these were water-powered machines is clear from his remark that their cost was only 10 to 20 percent that of "Pferden und Knechten."¹⁷ It is likely that many if not most were *Stangenkunst*, for mining treatises of the 17th and 18th centuries testify to the continuous extension of this mechanism.¹⁸

Perhaps the most striking evidence of its importance is its representation on the illustrated coinage of the 17th century. These multiple talers (figs. 1, 2, 3), happy products of the ingenious fiscal policies of the Dukes of Brunswick, picture mining activity in the 17th century no less elegantly than do the woodcuts of *De re metallica* a century earlier. The *Stangenkunst* received its most spectacular application in France, in its application to the driving of the second- and third-stage pumps in the famous waterworks at Marly (1681-88), but

¹⁶ I have been unable to find an early reference to this innovation, which appears in a sketch of 1784-85 illustrating Conrad Martschoss', "Die Maschinen des deutschen Berg- und Hüttenwesens vor 100 Jahren," *Beiträge zur Geschichte der Technik und Industrie* (1909), Band I, p. 7. Its introduction may be connected with the appearance of the team *Rosskunst* for the horse windlass, known earlier as the *Göpel*.

¹⁷ "Bericht des Bergverwalters Martin Planer über den Stand des Freiburger Bergbaues im Jahre 1570," ed. R. Wengley, *Mitteilungen Freiburger Altertumsverein*, 1898, vol. 35, pp. 75-83.

¹⁸ The description of the *Stangenkunst* in its various modifications is one of the chief topics of the previously cited work of Calvör (footnote 15), and from his and other references it is clear that the subject was also treated extensively by such earlier writers as Lohnevss (1617) and Rössler (1700).



FIGURE 7. FELDESTANGE (STANGENKUNST) NEAR LAUFENAU. From C. Martschoss, *Technische Entwicklungsgeschichte*, Munich, 1932.

its real importance is better illustrated in central Europe, by the many descriptions and drawings showing its use in the mines, driving machinery as distant as a mile¹⁹ from the source of power.

It seems, therefore, that Lohnevss' "old miners" were those described by Agricola, and that the mine-hauling machinery used in central European mines changed in the century after him far more than has been recognized.²⁰ This thesis may further cast some light on other technological questions. The

¹⁹ Frische and Wagenbreth, *op. cit.* (footnote 14), p. 112.

²⁰ The hauling of ores, as opposed to water, seems to have remained as shown by Agricola until the end of the 17th century. In 1694, however, the famous Swedish engineer Christopher Polhem built at Falun a water-powered conveyor system which brought the ore from the point of origin in the mine to the smelter in a single operation, terminating with the automatic unloading of the buckets (Vogel, *op. cit.*, footnote 10, p. 306).

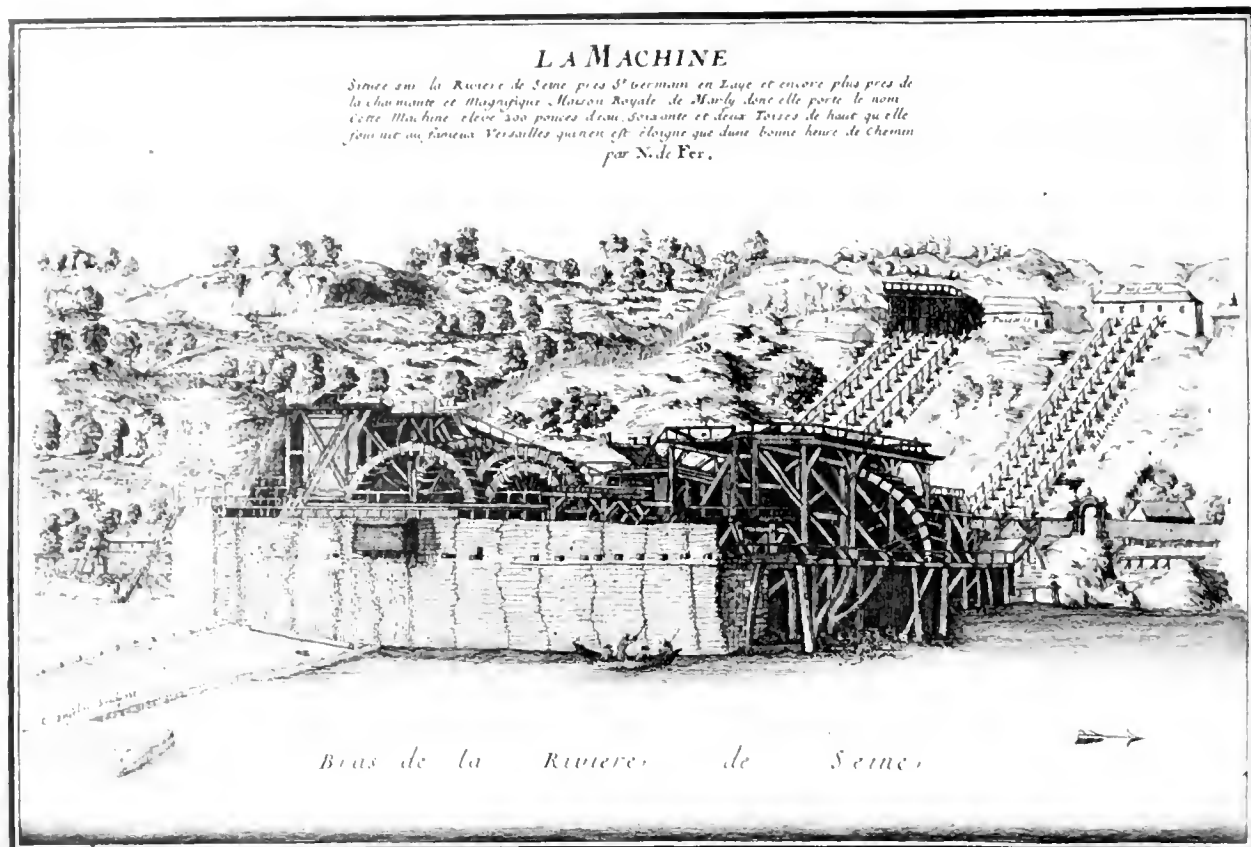


Figure 8. THE WATERWORKS AT MARLY-LE-ROI, ON THE SEINE RIVER, BUILT IN 1684 TO SUPPLY THE FOUNTAINS AT THE ROYAL PALACE AT VERSAILLES. From a print by de Fer, 1705. (Smithsonian photo 4593.)

connection between the urgency of the problem of mine drainage in England, and the invention of the steam engine, has often been suggested.²¹ Perhaps the “backwardness” of Germany in steam-engine experimentation, and later in the introduction of the Newcomen engine, was to some extent due to the adequacy of existing machinery to meet the problem of mine flooding, for it is not clear that this problem existed on the continent.²²

²¹ Dickinson, H. W., *A short history of the steam engine*, New York, n. d., p. 3.

²² In 1673 Edward Browne visited Hungary and the Erzgebirge. His report on the trip, *A brief account of some travels in divers parts of Europe* (2nd ed., London, 1685, p. 170), says little about machinery, but does not mention flooding as a serious problem. Of an 84-fathom mine called Auff der Halsbrucker, near Freiberg, he says “they are not so much troubled with water, and have very good engines to draw

A comparison of the techniques described by Agricola with those of a century later suggests that this was a century of significant progress in that earlier industrial revolution described by Mumford as his “Lotechnic phase,” characterized by “the diminished use of human beings as prime movers, and the separation of the production of energy from its application and immediate control.”²³

water out.” Yet the chain of dippers and rag and chain pump were evidently fallen into disuse, as they do not appear among the mining machines reported by Fritsche and Wagenbreth as having been described by Lohneyss (1617) or Rössler (1700); and Fritsche and Wagenbreth declare that German hydraulic machinery was able to compete with the steam engine in mine dewatering for some time into the 19th century (*op. cit.*, footnote 14, pp. 111, 112).

²³ Lewis Mumford, *Technics and civilization*, New York, 1934, p. 112.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 8

THE NATURAL PHILOSOPHY OF
WILLIAM GILBERT AND HIS PREDECESSORS

W. James King

THE NATURAL PHILOSOPHY OF WILLIAM GILBERT AND HIS PREDECESSORS

Until several decades ago, the physical sciences were considered to have had their origins in the 17th century—mechanics beginning with men like Galileo Galilei and magnetism with men like the Elizabethan physician and scientist William Gilbert.

Historians of science, however, have traced many of the 17th century's concepts of mechanics back into the Middle Ages. Here, Gilbert's explanation of the loadstone and its powers is compared with explanations to be found in the Middle Ages and earlier.

From this comparison it appears that Gilbert can best be understood by considering him not so much a herald of the new science as a modifier of the old.

THE AUTHOR: W. James King is curator of electricity, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.

THE YEAR 1600 saw the publication by an English physician, William Gilbert, of a book on the loadstone. Entitled *De magnete*,¹ it has traditionally been credited with laying a foundation for the modern science of electricity and magnetism. The following essay is an attempt to examine the basis

for such a tradition by determining what Gilbert's original contributions to these sciences were, and to make explicit the sense in which he may be considered as being dependent upon earlier work. In this manner a more accurate estimate of his position in the history of science may be made.

One criterion as to the book's significance in the history of science can be applied almost immediately. A number of historians have pointed to the introduction of numbers and geometry as marking a watershed between the modern and the medieval understanding of nature. Thus A. Koyré considers the Archimedeanization of space as one of the necessary features of the development of modern astronomy and physics.² A. N. Whitehead and E. Cassirer have turned to measurement and the quantification of force as marking this transition.³ However, the

¹ William Gilbert, *De magnete, magneticisque corporibus et de arte magnetica, physiologia nova, plurimus & argumentis, & perimetricis demonstrata*, London, 1600, 240 pp., with an introduction by Edward Wright. All references to Gilbert in this article, unless otherwise noted, are to the American translation by P. Henry Mottelay, 368 pp., published in New York in 1893, and are designated by the letter M. However, the Latin text of the 1600 edition has been quoted wherever I have disagreed with the Mottelay translation.

A good source of information on Gilbert is Dr. Duane H. D. Roller's doctoral thesis, written under the direction of Dr. F. B. Cohen of Harvard University. Dr. Roller, at present Curator of the De Golyer Collection at the University of Oklahoma, has informed me that an expanded version of his dissertation will shortly appear in book form. Unfortunately his researches were not known to me until after this article was completed.

² Alexandre Koyré, *Études galiléennes*, Paris, 1939.

³ Alfred N. Whitehead, *Science and the modern world*, New York, 1925, ch. 3; Ernst Cassirer, *Das Erkenntnisproblem*, ed. 3, Berlin, 1922, vol. 1, pp. 314-318, 352-359.

G V I L I E L M I G I L
 B E R T I C O L C E S T R E N
 S I S, M E D I C I L O N D I
 N E N S I S,

D E M A G N E T E, M A G N E T I
 C I S, Q U E C O R P O R I B V S, E T D E M A G
 n o. m a g n e t e t e l l u r e; P h y s i o l o g i a n o u a,
 p l u r i m i s & a r g u m e n t i s, & e x p e
 r i m e n t i s d e m o n s t r a t a.



L O N D I N I E

E X C V D E B A T P E T R V S S H O R T A N N O
 M D C.

Figure 1. WILLIAM GILBERT'S BOOK ON THE LOADSTONE. Title Page of the First Edition, FROM A COPY IN THE LIBRARY OF CONGRESS. (Part of a copy in the Library of Congress)

obvious absence⁴ of such techniques in *De magnete* makes it difficult to consider Gilbert as a founder of modern electricity and magnetism in this sense.

There is another sense in which it is possible to contend that Gilbert's treatise introduced modern studies in these fields. He has frequently been credited with the introduction of the inductive method based upon stubborn facts, in contrast to the methods and content of medieval Aristotelianism.⁵ No science can be based upon faulty observations and certainly much of *De magnete* was devoted to the destruction of the fantastic tales and occult sympathies of the Romans, the medieval writers, and the Renaissance. However, let us also remember that Gilbert added few novel empirical facts of a fundamental nature to previous observations on the loadstone. Gilbert's experimental work was in large part an expansion of Petrus Peregrinus' *De magnete* of 1269,⁶ and a development of works like Robert Norman's *The new attractive*,⁷ in which the author discussed how one could show experimentally the declination and inclination of a magnetized needle, and like William Borough's *Discourse on the variation of the compass or magnetized needle*,⁸ in which the author suggested the use of magnetic declination and inclination for navigational purposes but felt too little was known about it. That other sea-going nations had been considering

using the properties of the magnetic compass to solve their problems of navigation in the same manner can be seen from Simon Stevin's *De havenvinding*.⁹

Instead of new experimental information, Gilbert's major contribution to natural philosophy was that revealed in the title of his book—a new philosophy of nature, or physiology, as he called it, after the early Greeks. Gilbert's attempt to organize the mass of empirical information and speculation that came from scholars and artisans, from chart and instrument makers, made him “the father of the magnetic Philosophy.”¹⁰

Gilbert's *De magnete* was not the first attempt to determine the nature of the loadstone and to explain how it could influence other loadstones or iron. It is typical of Greek philosophy that one of the first references we have to the loadstone is not to its properties but to the problem of how to explain these properties. Aristotle¹¹ preserved the solution of the first of the Ionian physiologists: “Thales too . . . seems to suppose that the soul is in a sense the cause of movement, since he says that a stone has a soul because it causes movement to iron.” Plato turned to a similar animistic explanation in his dialogue, *Ion*.¹² Such an animistic solution pervaded many of the later explanations.

That a mechanical explanation is also possible was shown by Plato in his *Timaeus*.¹³ He argued that since a vacuum does not exist, there must be a plenum throughout all space. Motion of this plenum can carry objects along with it, and one could in this manner explain attractions like that due to amber and the loadstone.

Another mechanical explanation was based upon a postulated tendency of atoms to move into a vacuum rather than upon the latter's non-existence. Lucretius restated this Epicurean explanation in his

⁴ However, see M: pp. 161, 162, 168, 335.

⁵ For example, William Whewell, *History of the inductive sciences*, ed. 3, New York, 1858, vol. 2, pp. 192 and 217; Charles Singer, *A short history of science to the nineteenth century*, Oxford, 1943, pp. 188 and 343; and A. R. Hall, *The scientific revolution*, Boston, 1956, p. 185.

⁶ *Petri Peregrini maricometens, de magnete, seu rota perpetui motus, libellus*, a reprint of the 1558 Angsburg edition in J. G. G. Hellmann, *Rara magnetica*, Berlin, 1898, not paginated. A number of editions of Peregrinus' work, both ascribed to him and plagiarized from him, appeared in the 16th century (see Heinz Balmer, *Beiträge zur Geschichte der Erkenntnis des Erdmagnetismus*, Aarau, 1956, pp. 249–255).

⁷ Hellmann, *ibid.*, Robert Norman, *The newe attractive, containing a short discourse of the magnes or lodestone, and amongst other his vertues, of a newe discovered secret and subtill propertie, concerning the declining of the needle, touched therewith under the plane of the horizon. Nowe first founde out by Robert Norman Hydrographer*, London, 1581. The possibility is present that Norman's work was a direct stimulus to Gilbert, for Wright's introduction to *De magnete* stated that Gilbert started his study of magnetism the year following the publication of Norman's book.

⁸ Hellman, *ibid.*, William Borough, *A discourse of the variation of the compass, or magnetically needle. Wherin is mathematically showed, the manner of the observation, effects, and application thereof, made by W. B. And is to be annexed to the newe attractive of R. N.* London, 1596.

⁹ Hellman, *ibid.*, Simon Stevin, *De havenvinding*, Leyden, 1599. It is interesting to note that Wright translated Stevin's work into English.

¹⁰ As Edward Wright was to call him in his introduction.

¹¹ Aristotle, *On the soul*, translated by W. S. Hett, Loeb Classical Library, London, 1935, 405a20 (see also 411a8: “Some think that the soul pervades the whole universe, whence perhaps came Thales' view that everything is full of gods”).

¹² Plato, *Ion*, translated by W. R. M. Lamb, Loeb Classical Library, London, 1925, 533 (see also 536).

¹³ Plato, *Timaeus*, translated by R. G. Bury, Loeb Classical Library, London, 1929, 80. It is difficult to determine which explanation Plato preferred, for in both cases the speaker may be only a foil for Plato's opinion rather than an expression of these opinions.

De rerum natura.¹⁴ Atoms from the loadstone push away the air and tend to cause a vacuum to form outside the loadstone. The structure of iron is such that it, unlike other materials, can be pushed into this empty space by the thronging atoms of air beyond it.

Galen¹⁵ returned to a quasi-animistic solution in his denial of Epicurus' argument, which he stated somewhat differently from Lucretius. One can infer that Galen held that all things have, to a greater or lesser degree, a sympathetic faculty of attracting its specific, or proper, quality to itself.¹⁶ The loadstone is only an inanimate example of what one finds in nutritive organs in organic beings.

One of the few writers whose explanations of the loadstone Gilbert mentioned with approval is St. Thomas Aquinas. Although the medieval scholastic philosophy of St. Thomas seems foreign to our way of thinking, it formed a background to many of Gilbert's concepts, as well as to those of his predecessors, and it will assist our discussion to consider briefly Thomist philosophy and to make its terminology explicit at this point.¹⁷

In scholastic philosophy, all beings and substances are a coalescence of inchoate matter and enacting form. Form is that which gives being to matter and which is responsible for the "virtus" or power to cause change, since matter in itself is inert. Moreover, forms can be grasped intellectually, whence the nature of a being or a substance can be known. Any explanation of phenomena has to be based upon these innate natures, for only if the nature of a substance is known can its properties be understood. Inanimate natures are determined by observation, abstraction, and induction, or by classification.¹⁸

The nature of a substance is causally prior to its properties; while the definition of the nature is logically prior to these properties. Thus, what we call

¹⁴ Lucretius, *De rerum natura*, translated by W. H. D. Rouse, Loeb Classical Library, London, 1924, bk. VI, lines 998-1041.

¹⁵ Galen, *On the natural faculties*, translated by A. S. Brock, Loeb Classical Library, London, 1916, bk. 1 and bk. 3. A view similar to this appeared in Plato, *Timaeus*, 81 (see footnote 13).

¹⁶ This same concept was to reappear in the Middle Ages as the *inclinatio ad simile*.

¹⁷ The background for much of the following was derived from Annaliese Maier, *An der Grenze von Scholastik und Naturwissenschaft*, ed. 2, Rome, 1952.

¹⁸ St. Thomas' epistemology for the natural inanimate world was based upon Aristotle's dictum: that which is in the mind was in the senses first.

the theory of a substance is expressed in its definition, and its properties can be deduced from this definition.

The world of St. Thomas is not a static one, but one of the Aristotelian motions of quantity (change of size), of quality (alteration), and of place (local motion). Another kind of change is that of substance, called generation and corruption, but this is a mutation, occurring instantly, rather than a motion, that requires time. In mutation the essential nature is replaced by a new substantial form.

All these changes are motivated by a causal hierarchy that extends from the First Cause, the "Dator Formarum," or Creator, to separate intellectual substances that may be angels or demons, to the celestial bodies that are the "generantia" of the substantial forms of the elements and finally to the four prime qualities (dry and wet, hot and cold) of the substantial forms. Accidental forms are motivated by the substantial forms through the instrumentality of the four prime qualities, which can only act by material contact.

The only causal agents in this hierarchy that are learned through the senses are the tangible qualities. Usually the prime qualities are not observed directly, but only other qualities compounded of them. One of the problems of scholastic philosophy was the incorporation, into this system of efficient agents, of other qualities, such as the qualities of gravity and levity that are responsible for upward and downward motion.

Besides the causal hierarchy of forms, the natural world of St. Thomas existed in a substantial and spatial hierarchy. All substances whether an element or a mixture of elements have a place in this hierarchy by virtue of their nature. If the material were removed from its proper place, it would tend to return. In this manner is obtained the natural downward motion of earth and the natural upward motion of fire.

Local motion can also be caused by the "virtus coeli" generating a new form, or through the qualitative change of alteration. Since each element and mixture has its own natural place in the hierarchy of material substances, and this place is determined by its nature, changes of nature due to a change of the form can produce local motion. If before change the substance is in its natural place, it need not be afterwards, and if not, would then tend to move to its new natural place.

It will be noted that the scholastic explanation of

inanimate motion involved the action and passion of an active external mover and a passive capacity to be moved. Whence the definition of motion that Descartes¹⁹ was later to deride, "motus est actus entis in potentia prout quod in potentia."

We have seen above that the "motor essentialis" for terrestrial change is the "virtus coeli." Thus the enacting source of all motion and change is the heavens and the heavenly powers, while the earth and its inhabitants becomes the focus or passive recipient of these actions. In this manner the scholastic restated in philosophical terms the drama of an earth-centered universe.

Although change or motion is normally effected through the above mentioned causal hierarchy, it is not always necessary that actualization pass from the First Cause down through each step of the hierarchy to terminate in the qualities of the individual being. Some of the steps could be by-passed; for instance man's body is under the direct influence of the celestial bodies, his intellect under that of the angels and his will under God.²⁰ Another example of effects not produced through the tangible prime qualities is that of the tide-producing influence of the moon on the waters of the ocean or the powers of the loadstone over iron. Such causal relations, where some members of the normal causal chain have been circumvented, are called occult.²¹

While St. Thomas referred to the loadstone in a number of places as something whose nature and occult properties are well known, it was always as an example or as a tangential reference. One does not find a systematic treatment of the loadstone in St. Thomas, but there are enough references to

provide a fairly explicit statement of what he considered to be the nature of the magnet.

In one of his earliest writings, St. Thomas argued that the magnet attracts iron because this is a necessary consequence of its nature.²²

Respondeo dicendum, quod omnibus rebus naturaliter insunt quaedam principia, quibus non solum operationes proprias efficere possunt, sed quibus etiam eas convenientes fini suo reddant, sive sint actiones quae consequantur rem aliquam ex natura sui generis, sive consequantur ex natura speciei, ut magneti competit ferri deorsum ex natura sui generis, et attrahere ferrum ex natura speciei. Sicut autem in rebus agentibus ex necessitate naturae sunt principia actionum ipsae formae, a quibus operationes proprie prodeunt convenientes fini. . . .

Due to its generic form, the loadstone is subject to natural motion of place of up and down. However, the "virtus" of its specific form enabled it to produce another kind of motion – it could draw iron to itself.

Normally the "virtus" of a substance is limited to those contact effects that could be produced by the form operating through the active qualities of one substance, on the relatively passive qualities of another. St. Thomas asserted the loadstone to be one of these minerals, the occult powers of whose form goes beyond those of the prime qualities.²³

Forma enim elementi non habet aliquam operationem nisi quae fit per qualitates activas et passivas, quae sunt dispositiones materiae corporalis. Forma autem corporis mineralis habet aliquam operationem excedentem qualitates activas et passivas, quae consequitur speciem ex influentia corporis coelestis, ut quod magnes attrahit ferrum, et quod saphirus curat apostema.

That this occult power of the loadstone is a result of the direct influence of the "virtus coeli" was

¹⁹ René Descartes, *Oeuvres*, Charles Adam and Paul Tannery, Paris, 1897–1910, vol. 2, p. 597 (letter to Mersenne, 16 Oct., 1639), and vol. 11 (*Le Monde*), p. 39. The original definition can be found in Aristotle, *Physics*, translated by P. H. Wickstead and F. M. Cornford, Loeb Classical Library, London, 1934, 201a10. Aquinas rephrases the definition as "Motus est actus existentis in potentia secundum quod huius modi." See St. Thomas Aquinas, *Opera omnia*, Antwerp, 1612, vol. 2, *Physiologia Aristotelis expositio*, lib. 3, lect. 2, cap. a, p. 29.

²⁰ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 9, *Summa contra gentiles*, lib. 3, cap. 92 (Quo modo dicitur aliquis bene fortunatus et quo modo adjuvatur homo ex superioribus causis), p. 343.

²¹ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 17 *Opuscula, De operationibus occultis naturae ad quendam militem ultramontem*, pp. 213–224.

²² St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 7, *Scriptum in quartum librum sententiarum magistri Petri Lombardi*, lib. 4, disp. 33 (De diversis coniugii legibus), art. 1 (Utrum habere plures uxores sit contra legem naturae), p. 168. The same statement occurs in one of his most mature works, *op. cit.* vol. 20, *Summa theologiae*, pars 3 (supplementum), quaestio 65 (De pluralitate uxorum in quinque articulos divisa), art. 1 (Utrum habere plures uxores sit contra legem naturae), p. 107.

²³ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 8, *Quaestio unica: de spiritualibus creaturis*, art. 2 (Utrum substantia spiritualis possit uniri corpori), p. 404. See also vol. 9, *Summa contra gentiles*, lib. 3, cap. 92 (Quomodo dicitur aliquis bene fortunatus, et quomodo adjuvatur homo ex superioribus causis), p. 344; and vol. 17, *Opuscula, De operationibus occultis naturae ad quendam militem ultramontem*, pp. 213–214.

expounded at greater length in his treatise on the soul.²⁴

Quod quidem ex propriis formarum operationibus perpendi potest. Formae enim elementorum, quae sint infimae et materiae propinquissime, non habent aliquam operationem excedentem qualitates activas et passivas, ut rarum et densum, et aliae huiusmodi, qui videntur esse materiae dispositiones. Super has autem sunt formae mistorum quae praeter praedictas operationes, habent aliquam operationem consequentem speciem, quam fortuntur ex corporibus coelestibus; sicut quod magnes attrahit ferrum non propter calorem aut frigiditatem, aut aliquid huiusmodi; sed ex quadam participatione virtutis coelestis. Super has autem formas sunt iterum animae plantarum, quae habent similitudinem non solum ad ipsa corpora coelestia, sed ad motores corporum coelestium, in quantum sunt principia cuiusdam motus, quibusdam seipsa moventibus. Super has autem ulterius sunt animae brutorum, quae similitudinem iam habent ad substantiam moventem coelestia corpora, non solum in operatione qua movent corpora, sed etiam in hoc quod in seipsis cognoscitivae sunt, licet brutorum cognitio sit materialium tantum et materialiter. . . .

St. Thomas placed the form of the magnet and its powers in the hierarchy of forms intermediate between the forms of the inanimate world and the forms of the organic world with its hierarchy of plant, animal and rational souls. The form of the loadstone is then superior to that of iron, which can only act through its active and passive qualities, but inferior to the plant soul, that has the powers of growth from the "virtus coeli." This is similar to Galen's comparison of the magnet's powers to that of the nutritive powers of organic bodies.

In his commentary on Aristotle's *Physics*, St. Thomas explained how iron is moved to the magnet. It is moved by some quality imparted to the iron by the magnet.²⁵

Illud ergo trahere dicitur, quod movet alterum ad seipsum. Movere autem aliquid secundum locum ad seipsum contingit tripliciter. Uno modo sicut finis movet; unde et finis dicitur trahere, secundum illud poetate: "trahit sua quemque voluptas"; et hoc modo potest dici quod

²⁴ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 8, *Quaestio unice: de anima*, art. 1 (Utrum anima humana possit esse forma et hoc aliquid), p. 437. See also vol. 8, *Quaestio: De veritate*, quaestio 5 (De providentia), art. 10 (Utrum humani actus a divina providentia gubernentur mediis corporibus coelestibus), p. 678.

²⁵ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 2, *Physicorum Aristotelis expositio*, lib. 7, lect. 3, cap. g (Probatur in motu locali quod movens et motum oportet esse simul), p. 97 (quoted in Gilbert, M: p. 104).

locus trahit id, quod naturaliter movetur ad locum. Alio modo potest dici aliquid trahere, quia movet illud ad seipsum alterando aliquid, ex qua alteratione contingit quod alteratum moveatur secundum locum, et hoc modo magnes dicitur trahere ferrum. Sicut enim generans movet gravia et levia, in quantum dat eis formam per quam moventur ad locum, ita et magnes dat aliquam qualitatem ferro, per quam movetur ad ipsum. Et quod hoc sit verum patet ex tribus. Primo quidem quia magnes non trahit ferrum ex quacumque distantia, sed ex propinquo; si autem ferrum moveretur ad magnetem solum sicut ad finem, sicut grave ad suum locum, ex qualibet distantia tenderet ad ipsum. Secundo, quia, si magnes aliis perungatur, ferrum attrahere non potest; quasi aliis vim alterativam ipsius impediens, aut etiam in contrarium alterantibus. Tertio, quia ad hoc quod magnes attrahat ferrum, oportet prius ferrum limi cum magnete, maxime si magnes sit parvus; quasi ex magnete aliquam virtutem ferrum accipiat ut ad eum moveatur. Sic igitur magnes attrahit ferrum non solum sicut finis, sed etiam sicut movens et alterans. Tertio modo dicitur aliquid attrahere, quia movet ad seipsum motu locali tantum. Et sic definitur hic tractio, prout unum corpus trahit alterum, ita quod trahens simul moveatur cum eo quod trahitur.

As the "generans" of terrestrial change moves what is light and heavy to another place by implanting a new form in a substance, so the magnet moves the iron by impressing upon it the quality by which it is moved. By virtue of the new quality, the iron is not in its natural place and moves accordingly. St. Thomas proved that the loadstone acts as a secondary "generans" in three ways: (1) the loadstone produces an effect not from any distance but only from a nearby position (showing that this motion is due to more than place alone), (2) rubbing the loadstone with garlic acts as if it impedes or alters the "virtus magnetis," and (3) the iron must be properly aligned with respect to the loadstone in order to be moved, especially if the loadstone is small. Thus the iron is moved by the magnet not only to a place, but also by changing and altering it; one has not only the change of locomotion but that of alteration. Moreover the source of this alteration in the iron is not the heavens but the loadstone. Accordingly the loadstone could cause change in another substance because it could influence the nature of the other substance.

About the time that St. Thomas was writing his letter *De operationibus occultis naturae* to a certain knight, Petrus Peregrinus was writing from a military camp a letter in which he showed how certain relatively new effects could be produced by the loadstone:

He was more interested in what he could do with the magnet than in explaining these effects. However, he discussed it at sufficient length for one to find that his explanation of magnetic phenomena was basically similar to that of his contemporary, St. Thomas.

Peregrinus based his discussion of the loadstone upon its nature and analyzed magnetic phenomena in terms of the change of alteration. In magnetic attraction, the nature of the iron is altered by having a new quality impressed upon it,²⁶ and the loadstone is the agent that makes the iron the same species as the stone.²⁷

... Oportet enim quod illud quod iam conversum est ex duobus in unum, sit in eadem specie cum agente; quod non esset, si natura istud impossibile eligeret.

This impressed similarity to the agent, Peregrinus realized, is not a pole of the same polarity but one opposite to that of the inducing pole. To produce this effect, the virtue of the stronger agent dominates the weaker patient and impresses the virtue of the stronger on the weaker so that they are made similar.²⁸

... In cuius attractione, lapis fortioris virtutis agens est; debilioris vero patiens.

A further instance of alteration occurs in the reversal of polarity of magnetized iron when one brings two similar poles together. Again, the stronger agent dominates the weaker patient and the iron is left with a similarity to the last agent.²⁹

... Causa huius est impressio ultimi agentis, confundentis et alterantis virtutem primi.

In this assimilation of the agent to the patient, another effect is produced: the agent not only desires to assimilate the patient to itself, but to unite with it to become one and the same. Speaking of the motion to come together, he says:³⁰

Huius autem rei causam per hanc viam fieri existimo: agens enim intendit summi patiens non solum sibi assimilare, sed unire, ut ex agente et patiente fiat unum, per numerum. Et hoc potes experiri in isto lapide mirabili in hunc modum. ... Agens ergo, ut vides experimento, intendit summi patiens sibi unire; hoc autem fit ratione similitudinis inter ea.

²⁶ Hellmann, *op. cit.* (footnote 6), Peregrinus, pt. 1, ch. 8. The magnet attracts the iron "secundum naturalem appetitum lapidis . . . sine resistentia." There is no natural resistance to this motion since it is no longer contrary to the nature of the iron. The nature of the iron has changed.

²⁷ *Ibid.*, pt. 1, ch. 9.

²⁸ *Ibid.*, pt. 1, ch. 9.

²⁹ *Ibid.*, pt. 1, ch. 8.

³⁰ *Ibid.*, pt. 1, ch. 9.

Oportet ergo . . . virtute attractionis, fiat una linea, ex agente et patiente, secundum hunc ordinem . . .

The nature of the magnet, as an active cause, tends to enact, and since it acts in the best manner in which it is able, it acts so as to preserve the similarities of opposite poles.³¹

Natura autem, que tendet ad esse, agit meliori modo quo potest, eligit primum ordinem actionis, in quo melius salvatur idemptitas, quam in secundo . . .

Thus unlike poles tend to come together when a dissected magnet is reassembled.

Like St. Thomas, Peregrinus argued that the magnet receives its powers from the heavens. But he further specified this by declaring that different virtues from the different parts of the heavens flow into their counterpart in the loadstone—from the poles of the heavens the virtue flows into the poles of the magnet.³²

Præterea cum ferrum, vel lapis, vertatur tam ad partem meridionalem quam ad partem septentrionalem . . . existima cogimur, non solum a partem septentrionali, verum etiam a meridionali virtutem influî in polos lapidis, magis quam a locis minere . . . Omnes autem orbes meridiani in polis mundi concurrunt; quare, a polis mundi, poli magnetis virtutem recipiunt. Et ex hoc apparet manifeste quod non ad stellam nauticam movetur, cum ibi non concurrant orbes meridiani, sed in polis; stella enim nautica, extra orbem meridianum cuiuslibet regionis semper invenitur, nisi bis, in completa firmanenti revolutione. Ex hiis ergo manifestum est quod a partibus celi, partes magnetis virtutem recipiunt.

and similarly for the other parts of the heavens and the other parts of the loadstone.³³

Ceteras autem partes lapidis merito estimare potes, influentiam a reliquis celi partibus retinere, ut non sic solum polos lapidis a polis mundi, sed totum lapidem a toto celo, recipere influentiam et virtutem, estimes.

Physical proof for such influences was adduced by Peregrinus from the motions of the loadstone. That the poles of the loadstone receive their virtue from the poles of the heavens follows experimentally from north-south alignment of a loadstone. That not only the poles but the entire loadstone receives power from corresponding portions of the heavens follows from the fact that a spherical loadstone, when "properly balanced," would follow the motion of the heavens.³⁴

³¹ *Ibid.*, pt. 1, ch. 9. See also footnote 27.

³² *Ibid.*, pt. 1, ch. 10. See also ch. 4.

³³ *Ibid.*, pt. 1, ch. 10. See also ch. 4.

³⁴ *Ibid.*, pt. 1, ch. 10.

Quod tibi tali modo consulo experire: Et si tunc lapis moveatur secundum celi motum, gaudeas te esse assecutum secretum mirabile; si vero non, imperitiae tuae, potiusquam naturae, defectus imputetur. In hoc autem situ, seu modo positionis, virtutes lapidis huius aestimo conservari proprie, et in reliquis sitibus celi virtutem eius obsecari, seu ebetari, potiusquam conservari puto. Per hoc autem instrumentum excusaberis ab omni horologio; nam per ipsum scire poteris Ascensus in quacunque hora volueris, et omnes alias celi dispositiones, quas querunt Astrologi.

As the heavens move eternally, so the spherical loadstone must be a "perpetuum mobile".

Another of the scholars whose explanation of the loadstone Gilbert noted with approval was Cardinal Nicholas of Cusa.³⁵ The latter's references to it were not as direct as those of St. Thomas, but he did use it as an image several times to provide a microcosmic example of the relation of God to his creation. From this one can infer that he explained the preternatural motion of the magnet and the iron by impressed qualities, the heavens being the agent for the loadstone, and the loadstone, the agent for iron.

In the *Idiota de sapientia* the Cardinal used the image of the magnet and the iron to provide a concrete instance of his "coincidentia oppositorum," to illustrate how eternal wisdom, in the Neoplatonic sense, could, at the same time, be principle or cause of being, its complement and also its goal.³⁶

Si igitur in omni desiderio vitae intellectualis attenderes, a quo est intellectus, per quod movetur et ad quod, in te comperires dulcedinem sapientiae aeternae illam esse, quae tibi facit desiderium tuum ita dulce et delectabile, ut in inerrabili affectu feraris ad eius comprehensionem tanquam ad immortalitatem vitae tuae, quasi ad ferrum et magnetem attendas. Habet enim ferrum in magnete quoddam sui effluxus principium; et dum magnes per sui praesentiam excitat ferrum grave et ponderosum, ferrum mirabili desiderio fertur etiam supra motum naturae, quo secundum gravitatem deorsum tendere debet, et sursum movetur se in suo principio uniendo. Nisi enim in ferro esset quaedam praegustatio naturalis ipsius magnetis, non moveretur plus ad magnetem quam ad alium lapidem; et

nisi in lapide esset major inclinatio ad ferrum quam cuprum, non esset illa attractio. Habet igitur spiritus noster intellectualis ab aeterna sapientia principium sic intellectualiter essendi, quod esse est conformis sapientiae quam aliud non intellectuade. Hinc irradiatio seu immissio in sanctam animam est motus desideriosus in excitatione.

By virtue of the principle that flows from the magnet to the iron— which principle is potentially in the iron, for the iron already has a foretaste for it— the excited iron could transcend its gravid nature and be preternaturally moved to unite with its principle. Reciprocally, the loadstone has a greater attraction to the iron than to other things. Just as the power of attraction comes from the loadstone, so the Deity is the source of our life. Just as the principle implanted in the magnet moves the iron against its heavy nature, so the Deity raises us above our brutish nature so that we may fulfill our life. As the iron moves to the loadstone, so we move to the Deity as to the goal and end of our life.

In *De pace fidei*, Cusa³⁷ again used the iron and magnet as an example of motion contrary to and transcending nature. He explained this supernatural motion as being due to the similarity between the nature of the iron and the magnet, and this in turn is analogous to the similarity between human spiritual nature and divine spiritual nature. As the iron can move upward to the loadstone because both have similar natures, so man can transcend his own nature and move towards God when his potential similitude to God is realized. Another image used by Cusa was the comparison of Christ to the magnetic needle that takes its power from the heavens and shows man his way.³⁸

The Elizabethan Englishman Robert Norman also turned to the Deity to explain the wonderful effects of the loadstone.³⁹

Now therefore . . . divers have whetted their wits, yea, and dulled them, as I have mine, and yet in the end have been constrained to fly to the cornerstone: I mean God who . . . hath given Virtue and power to this Stone

³⁵ However, he may not always have approved of him. See M:74; "Overinquisitive theologians, too, seek to light up God's mysteries and things beyond man's understanding by means of the loadstone and amber."

³⁶ Nicholas of Cusa (Nicolaus Cusanus), *Nicolaus von Cusa, Texte seiner philosophischen Schriften*, ed. A. Petzelt, Stuttgart, 1949, bk. 1, *Idiota de sapientia*, p. 306 (quoted in Gilbert, M:104). It is interesting that Cusa held that the loadstone has an inclination to iron, as well as the converse!

³⁷ Cusa, *Cusa Schriften*, vol. 8, *De pace fidei*, translated by E. Mohler, Leipzig, 1943, ch. 12, p. 127.

³⁸ Cusa, *Excitationes*, ch. 7, 563 and 566, quoted in, F. A. Scharpff, *Des Cardinals und Bischofs Nic. Cusa Von Cusa, Heiligste Schriften in Deutscher Uebersetzung*, Freiburg, 1862, p. 435. See also Martin Billinger, *Das Philosophische in Des. Excitationes Des Nicolaus Von Cusa*, Heidelberg, 1938, and *Cusa Schriften* (see footnote 37), vol. 8, p. 209, note 105. Gilbert (M: p. 223) called the compass "the finger of God."

³⁹ Hellmann, *op. cit.* (footnote 6), Norman, bk. 1, ch. 8.

to show one certain point, by his own nature and appetite . . . and by the same vertue, the Needle is turned upon his own Center, I mean the Center of his Circular and invisible Vertue . . . And surely I am of opinion, that if this would be found in a Sphericall form, extending round about the Stone in Great Compass, and the dead body Stone in the middle therof: Whose center is the center of his aforesaid Vertue. And this I have partly proved, and made visible to be seen in the same manner, and God sparing me life, I will herein make further Experience.

Again, one can infer that the heavens impart a guiding principle to the iron which acts under the influence of this Superior Cause.

One of the points made in St. Thomas' argument on motion due to the loadstone was that there is a limit to the "virtus" of the loadstone, but he did not specify the nature of it. Norman refined the Thomist concept of a bound by making it spherical in form, foreshadowing Gilbert's "orbis virtutis."

Gilbert's philosophy of nature does not move far from scholastic philosophy, except away from it in logical consistency. As the concern of Aristotle and of St. Thomas was to understand being and change by determining the nature of things, so Gilbert sought to write a logos of the physis, or nature, of the loadstone—a physiology.⁴⁰ This physiology was not formally arranged into definitions obtained by induction from experience, but nevertheless there was the same search for the quiddity of the loadstone. Once one knew this nature then all the properties of the loadstone could be understood.

Gilbert described the nature of the loadstone in the terms of being that were current with his scholarly contemporaries. This was the same ontology that scholasticism had taught for centuries—the doctrine of form and matter that we have already found in St. Thomas and Nicholas of Cusa. Thus we find Richard Hooker⁴¹ remarking that form gives being and that "form in other creatures is a thing proportionable unto the soul in living creatures." Francis Bacon,⁴² in speaking of the relations between causes and the kinds of philosophy, said: "Physics is the science that deals with efficient and material causes

while Metaphysics deals with formal and final causes." John Donne⁴³ expressed the problem of scholastic philosophy succinctly:

This twilight of two yeares, not past or next,
Some embleme is of me, . . .
. . . of stulle and forme perplext,
Whose *chat* and *cherie*, in disputation is . . .

As we shall see, Gilbert continued in the same tradition, but his interpretation of form and formal cause was much more anthropomorphic than that of his predecessors.

Gilbert began his *De magnete* by expounding the natural history of that portion of the earth with which we are familiar.⁴⁴

Having declared the origin and nature of the loadstone, we hold it needful first to give the history of iron also . . . before we come to the explication of difficulties connected with the loadstone . . . we shall better understand what iron is when we shall have developed . . . what are the causes and the matter of metals . . .

His treatment of the origin of minerals and rocks agreed in the main with that of Aristotle,⁴⁵ but he departed somewhat from the peripatetic doctrine of the four elements of fire, air, water, and earth.⁴⁶ Instead, he replaced them by a pair of elements.⁴⁷ (If the rejection of the four Aristotelian elements were clearer, one might consider this a part of his rejection of the geocentric universe but he did not define his position sufficiently.)⁴⁸

According to Gilbert the primary source of matter is the interior of the earth, where exhalations and "spiritus" arise from the bowels of the earth and condense in the earth's veins.⁴⁹ If the condensations, or humors, are homogeneous, they constitute the

⁴³ *The poems of John Donne*, ed. H. J. C. Grierson, London, Oxford University Press, 1933, p. 175 ("To the Countesse of Bedford, On New Yeares Day").

⁴⁴ M: pp. 33, 34.

⁴⁵ M: pp. 34, 35. Aristotle, *Works*, ed. W. D. Ross, Oxford, 1908-1952, vol. 2, *De generatione et corruptione*, translated by H. H. Joachim, 1930, vol. 3, *Meteorologica*, translated by E. W. Webster, 1931.

⁴⁶ M: pp. 34, 35, 64, 65, 69, 81. Dr. H. Guerlac has kindly brought to my attention the similarity between the explanation given in Gilbert and that given in the *Meteorologica*, bk. 3, ch. 6 p. 378.

⁴⁷ M: p. 83.

⁴⁸ A statement of the relation between Aristotle's four elements and place can be found in Maier, *op. cit.* (footnote 17), pp. 143-182.

⁴⁹ M: pp. 21, 34, 35, 36, 45.

⁴⁰ M: p. 13.

⁴¹ Richard Hooker, *Of the laws of ecclesiastical polity*, bk. 1, ch. 3, sect. 4 (*Works*, Oxford, Clarendon Press, 1865, vol. 1, p. 157).

⁴² Francis Bacon, *De augmentis scientiarum*, bk. 3, ch. 4, in *Works*, ed. J. Spedding, R. L. Ellis, and D. D. Heath, Boston, n.d. (1900?), vol. 2, p. 267.

“materia prima” of metals.⁵⁰ From this “materia prima,” various metals may be produced,⁵¹ according to the particular humor and the specifying nature of the place of condensation.⁵² The purest condensation is iron: “In iron is earth in its true and genuine nature.”⁵³ In other metals, we have instead of earth, “condensed and fixed salts, which are efflorescences of the earth.”⁵⁴ If the condensed exhalation is mixed in the vein with foreign earths already present, it forms ores that must be smelted to free the original metal from dross by fire.⁵⁵ If these exhalations should happen to pass into the open air, instead of being condensed in the earth, they may return to the earth in a (meteoric) shower of iron.⁵⁶

Gilbert was indeed writing a new physiology, both in the ancient sense of the word and the modern. The process of the formation of metals had many biological overtones, for it was a kind of metallic epigenesis.⁵⁷ “Within the globe are hidden the principles of metals and stones, as at the earth’s surface are hidden the principles of herbs and plants.”⁵⁸ In all cases, the “spiritus” acts as semen and blood that inform and feed the proper womb in the generation of animals.⁵⁹ “The brother uterine of iron,”⁶⁰ the loadstone, is formed in this manner. As the embryo of a certain species is the result of the specifying nature of the womb in which the generic seed has been placed, so the kind of metal is the result of a certain humor condensing in a particular vein in the body of the earth.

Gilbert developed this biological analogy further by ascribing to metals a process of decay after reaching

⁵⁰ M: pp. 35, 36, 38, 69; see, however, pp. 42–43: “Iron ore, therefore, as also manufactured iron, is a metal slightly different from the homogenic telluric body because of the metallic humor it has imbibed . . .”

⁵¹ M: pp. 19, 34, 36, 37, 42, 69.

⁵² M: pp. 35, 36, 37, 38.

⁵³ M: pp. 38, 63, 69, 84; on p. 34 he says that iron is “more truly the child of the earth than any other metal”; it is the hardest because of “the strong concretion of the more earthy substance.”

⁵⁴ M: pp. 21, 35, 37, 38.

⁵⁵ M: pp. 35, 63.

⁵⁶ M: pp. 45, 46.

⁵⁷ Gilbert’s terminology strongly suggests that he was familiar with alchemical literature, as well as that of medical chemistry. He has been credited as being highly skilled in chemistry. See Sir Walter Langdon-Brown, “William Gilbert: his place in the medical world,” *Nature*, vol. 154, pp. 136–139, 1944.

⁵⁸ *Ibid.*, p. 37.

⁵⁹ M: pp. 35, 36, 53, 59. See also Galen, *op. cit.* (footnote 15) bk. 2, ch. 3.

⁶⁰ M: pp. 16, 59.

maturity. Once these solid materials have been formed, they will degenerate unless protected, forming earths of various kinds as a result.⁶¹ The “rind of the earth”⁶² is produced by this process of growth and decay. If these earths are soaked with humors, transparent materials are formed.⁶³

As we shall see below, the ultimate cause of this internal and superficial life is the motion of the earth, which animation is the expression of the magnetic soul of this sphere.⁶⁴ As the life of animals results from the constant working of the heart and arteries,⁶⁵ so the daily motion of the earth results in a constant generation of mineral life within the earth. In contrast to Aristotle’s⁶⁶ making the motion of the heavens the cause of continuous change, Gilbert made that of the earth the remote cause.⁶⁷ However, unlike the constant cyclical transmutation of substances in Aristotle, there is only generation and decay.

Gilbert made a number of successive generalizations in order to arrive at the induction that the form of the loadstone is a microcosmic “anima” of that of the earth.⁶⁸ After comparing the properties of the loadstone and of iron, his first step in this induction was that the two materials, found everywhere,⁶⁹ are consanguineous:⁷⁰ “These two associated bodies possess the true, strict form of one species, though because of the outwardly different aspect and the inequality of the selfsame innate potency, they have hitherto been held to be different . . .” Good iron and good loadstone are more similar than a good and a poor loadstone, or a good and a poor iron ore.⁷¹ Moreover, they have the same potency,⁷² for the innate potency of one can be passed to the other:⁷³ “The stronger invigorates the weaker, not as it imparts of its own substances or parted with aught

⁶¹ M: pp. 20, 21, 32, 61, 63, 66, 70.

⁶² M: p. 59.

⁶³ M: p. 84.

⁶⁴ M: pp. 310, 311, 312.

⁶⁵ M: p. 338. A somewhat different opinion, although not necessarily inconsistent is expressed on p. 66, where he says the surface is due to the action of the atmosphere, the waters, and the radiations and other influences of heavenly bodies.

⁶⁶ Aristotle, *op. cit.* (footnote 15), *De generatione et corruptione*, bk. 2, ch. 10.

⁶⁷ M: pp. 311, 334, 338.

⁶⁸ M: pp. 316, 309, 328.

⁶⁹ M: pp. 18, 20, 43, 46, 69.

⁷⁰ M: pp. 53, 61, 63.

⁷¹ M: pp. 69, 63.

⁷² M: p. 110.

⁷³ M: pp. 60, 61.

of its own strength, nor as if it injected into the other any physical substance; but rather the dormant power of the one is awakened by the other's without expenditure." In addition, the potency can be passed only to the other.⁷⁴ Finally they both have the same history:

We see both the finest magnet and iron ore visited as it were by the same ills and diseases, acting in the same way and with the same indications, preserved by the same remedies and protective measures, and so retaining their properties . . . they are both impaired by the action of acrid liquids as though by poison⁷⁵ . . . each is saved from impairment by being kept in the scrapings of the other. [So] . . . form, essence and appearance are one.⁷⁶

Any difference between the loadstone proper and the iron proper is due to a difference in the actual power of the magnetic virtue: ⁷⁷ "Weak loadstones are those disfigured with dross metallic humors and with foreign earth admixtures, [hence one may conclude] they are further removed from the mother earth and are more degenerate."

Gilbert's second induction was that they are "true and intimate parts of the globe,"⁷⁸ that is, that they are piece of the "materia prima" of all we see about us. For they "seem to contain within themselves the potency of the earth's core and of its inmost viscera."⁷⁹ Whence, in Gilbert's philosophy, the earthy matter of the elements was not passive or inert⁸⁰ as it was in Aristotle's, but already had the magnetic powers of loadstone. Being endowed with properties, it was, in peripatetic terms, a simple body.

If these pieces of earth proper, before decay, are loadstones, then one may pass to the next induction that the earth itself is a loadstone.⁸¹ Conversely, a terrella has all the properties of the earth: ⁸² "Every separate fragment of the earth exhibits in indubitable experiments the whole impetus of magnetic matter; in its various movements it follows the terrestrial globe and the common principle of motion."⁸³

⁷⁴ M: p. 62.

⁷⁵ M: p. 63.

⁷⁶ M: p. 60.

⁷⁷ M: pp. 19, 21, 43, 53, 61, 63, 184.

⁷⁸ M: p. 61.

⁷⁹ M: pp. 66, 67.

⁸⁰ M: p. 69. Gilbert is confusing Aristotelian matter and an element. He includes cold and dry, with formless and inert! See also Maier, *op. cit.* (footnote 17).

⁸¹ M: p. 63; bk. 1, ch. 17.

⁸² M: pp. 67, 181-183, 235-240, 281-289, 313-314.

⁸³ M: p. 71. See also pp. 314 and 331. It is not clear, at this point, whether he believed a "properly balanced" terrella would be a *perpetuum mobile*.

The next induction that Gilbert made was that as the magnet possesses verticity and turns towards the poles, so the loadstone-earth possesses a verticity and turns on an axis fixed in direction.⁸⁴ He could now discuss the motions of a loadstone in general, in terms of its nature, just as an Aristotelian discussed the motion of the elements in terms of their nature.

But before reaching this point in his argument, Gilbert digressed to classify the different kinds of attractions and motions which the elements produce. In particular, he distinguished electric attraction from magnetic coition, and pointed out the main features of electrical attraction. Since the resultant motions were different, the essential natures of electric and magnetic substances had to differ.

Gilbert introduced his treatment of motion by discussing the attraction of amber. All sufficiently light solids⁸⁵ and even liquids,⁸⁶ but not flame or air⁸⁷ are attracted by rubbed amber. Heat from friction,⁸⁸ but not from alien sources like the sun⁸⁹ or the flame,⁹⁰ produce this "affection." By the use of a detector modeled after the magnetic needle, which we would call an electroscope but which he called a "versorium,"⁹¹ Gilbert was able to extend the list of substances that attract like amber.⁹² These Gilbert called "electricae."⁹³

Possibly as a result of testing experimentally statements like that of St. Thomas, on the effect of garlic on a loadstone, Gilbert discovered that the interposition of even the slightest material (except a fluid like olive oil) would screen the attraction of electrics.⁹⁴ Hence the attraction is due to a material cause, and, since it is invisible, it is due to an effluvia.⁹⁵ It must be much rarer than air,⁹⁶ for if its

⁸⁴ M: pp. 68, 70-71, 97, 129, 179-180, 311, 315, 317-335. Gilbert implied (M: p. 166), that a terrella does not rotate as Peregrius said, due to resistance (M: p. 326), or due to the mutual nature of coition (M: p. 166); or even to the rotation of the earth (M: p. 332). However (M: p. 129), he also mentioned that a terrella would revolve by itself!

⁸⁵ M: pp. 78, 82, 84, 86.

⁸⁶ M: pp. 78, 89, 91.

⁸⁷ M: pp. 89, 95.

⁸⁸ M: pp. 83, 86.

⁸⁹ M: pp. 81, 86, 87.

⁹⁰ M: pp. 80, 81, 86, 87.

⁹¹ M: p. 79.

⁹² M: pp. 77-78, 79.

⁹³ M: p. 78. The definition Gilbert gave of an electric in the glossary at the beginning of his treatise was not an experimental one: "Electricae, quae attrahunt eadem ratione ut electrum."

⁹⁴ M: pp. 86, 91, 135. ⁹⁵ M: pp. 96, 135.

⁹⁶ M: p. 89.

density were that of air or greater, it would repel rather than attract.⁹⁷

The source of the effluvia could be inferred from the properties of the electrics. Many but not all of the electrics are transparent, but all are firm and can be polished.⁹⁸ Since they retain the appearance and properties of a fluid in a firm solid mass,⁹⁹ Gilbert concluded that they derived their growth mostly from humors or were concretions of humors.¹⁰⁰ By friction, these humors are released and produce electrical attraction.¹⁰¹

This humoric source of the effluvia was substantiated by Gilbert in a number of ways. Electrics lose their power of electrical attraction upon being heated, and this is because the humor has been driven off.¹⁰² Bodies that are about equally constituted of earth and humor, or that are mostly earth, have been degraded and do not show electrical attraction.¹⁰³ Bodies like pearls and metals, since they are shiny and so must be made of humors, must also emit an effluvia upon being rubbed, but it is a thick and vaporous one without any attractive powers.¹⁰⁴ Damp weather and moist air can weaken or even prevent electrical attraction, for it impedes the efflux of the humor at the source and accordingly diminishes the attraction.¹⁰⁵ Charged bodies retain their powers longer in the sun than in the shade, for in the shade the effluvia are condensed more, and so obscure emission.¹⁰⁶

All these examples seemed to justify the hypothesis that the nature of electrics is such that material effluvia are emitted when electrics are rubbed, and that the effluvia are rarer than air. Gilbert realized that as yet he had not explained electrical attraction, only that the pull can be screened. The pull must be explained by contact forces,¹⁰⁷ as Aristotle¹⁰⁸ and

Aquinas¹⁰⁹ had argued. Accordingly, he declared, the effluvia, or "spiritus,"¹¹⁰ emitted take "hold of the bodies with which they unite, enfold them, as it were, in their arms, and bring them into union with the electrics."¹¹¹

It can be seen how this uniting action is effected if objects floating on water are considered, for solids can be drawn to solids through the medium of a fluid.¹¹² A wet body touching another wet body not only attracts it, but moves it if the other body is small,¹¹³ while wet bodies on the surface of the water attract other wet bodies. A wet object on the surface of the water seeks union with another wet object when the surface of the water rises between both: at once, "like drops of water, or bubbles on water, they come together."¹¹⁴ On the other hand, "a dry body does not move toward a wet, nor a wet to a dry, but rather they seem to go away from one another."¹¹⁵ Moreover, a dry body does not move to the dry rim of the vessel while a wet one runs to a wet rim.¹¹⁶

By means of the properties of such a fluid, Gilbert could explain the unordered coming-together that he called coacervation.¹¹⁷ Different bodies have different effluvia, and so one has coacervation of different materials. Thus, in Gilbert's philosophy air was the earth's effluvia and was responsible for the unordered motion of objects towards the earth.¹¹⁸

The analogy between electric attraction and fluids is a most concrete one, yet lying beneath this image is a hypothesis that is difficult to fix into a mechanical system based upon contact forces. This is the assumption that under the proper conditions bodies tend to move together in order to participate in a more

¹⁰⁹ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 2, *Physiologia, Aristotelis expositio*, lb. 7, lect. 2 (In moventibus et motis non potest procedi in infinitum, sed oportet devenire ad aliquid primum movens immobile), cap. d, p. 96.

¹¹⁰ M, p. 94.

¹¹¹ M, p. 95.

¹¹² M, p. 93.

¹¹³ M, pp. 92, 93.

¹¹⁴ M, p. 93.

¹¹⁵ M, p. 94.

¹¹⁶ M, p. 94.

¹¹⁷ M, p. 97.

¹¹⁸ M, p. 92 (see also p. 339). Although Gilbert does not make it explicit, this would solve the medieval problem of gravitation without resorting to a Ptolemaic universe. In addition, since coacervation is electric, and electric forces can be screened, it should have been possible to reduce the downward motion of a body by screening!

⁹⁷ M: pp. 90, 92, 95.

⁹⁸ M: pp. 83, 84, 85.

⁹⁹ M: p. 84.

¹⁰⁰ M: pp. 84, 89. See also Aristotle, *op. cit.* (footnote 45), *Meteorologica*, bk. 4.

¹⁰¹ M: p. 90.

¹⁰² M: pp. 84, 85.

¹⁰³ M: p. 84.

¹⁰⁴ M: p. 90. See also p. 95.

¹⁰⁵ M: pp. 78, 85-86, 91. (see particularly the heated amber experiment described on p. 86).

¹⁰⁶ M: p. 87.

¹⁰⁷ M: p. 92.

¹⁰⁸ Aristotle, *Physics*, translated by P. H. Wicksteed and F. M. Cornford, Loeb Classical Library, London, 1934, bk. 7, ch. 1, 242b25,

complete unity.¹¹⁹ The steps in electrical attraction were described as occurring on two different levels of abstraction: first one has physical contact through an effluvium or "spiritus" that connects the two objects physically. Then, as a result of this contact, the objects somehow sense¹²⁰ that a more intimate harmony is possible, and move accordingly. Gilbert called the motion that followed contact, attraction. However, this motion did not connote what we would call a force:¹²¹ it did not correspond directly to a push or pull, but it followed from what one might term the apprehension of the possibility of a more complete participation in a formal unity. The physical unity due to the "spiritus" was the prelude to a formal organic unity, so that *humor* is "rerum omnium unitore." Gilbert's position can be best seen in the following:¹²²

Spiritus igitur egrediens ex corpora, quod ab humore aut succo aqueo concreverat, corpus attrahendum attingit, attractum attrahenti unium; corpus peculiari effluviolorum radio continguum, unum efficit ex duobus: unita conflunt in conjunctissimam convenientiam, quae attractio vulgo dicitur. Quae unitas iuxta Pythagorae opinionem rerum omnium principium est, per cuius participationem unaquaeque res una dicitur. Quoniam enim nullo actio a materia potest nisi per contactum, electrica haec non videntur tangere, sed ut necesse erat demittitur aliquid ab uno ad aliud, quod proxime tangat, et eius incitationis principium sit. Corpora omnia uniumtur & quasi ferrumantur quodammodo humore . . . Electrica vero effl via peculiariora, quae humoris fusi subtilissima sunt materia, corpuscula allectant. Aer (commune effluviolum telluri & partes disjunctis unit, & tellus mediante aëre ad se revocat corpora; aliter quae in superioribus locis essent corpora, terram non ita avidè appellerent.

Electrica effluvia ab aëre multum differunt, & ut aer telluris effluviolum est, ita electrica suababent effluvia & propria; peculiaribus effluviis suis cuique; est singularis ad unitatem ductus, motus ad principium, fontem, & corpus effluvia emittens.

A similar hypothesis will reappear in his explanation of magnetic attraction.

Following the tradition of the medieval schoolmen Gilbert started his examination of the nature of the

¹¹⁹ M: pp. 91, 92: "This unity is, according to Pythagoras, the principle, through participation, in which a thing is said to be one" (see footnotes 30 and 122).

¹²⁰ "Sense" is probably too strong a term, and yet the change following contact is difficult to describe in Gilbert's phraseology without some such subjective term. See Gilbert's argument on the soul and organs of a loadstone, M: pp. 309-313.

¹²¹ M: pp. 112, 113.

¹²² Gilbert, *De magneté*, London, 1600, bk. 2, ch. 2, pp. 56-57.

loadstone by pointing out the different kinds of motion due to a magnet. The five kinds (other than up and down) are:¹²³

- (1) coitio (vulgo attractio, dicta) ad unitatem magneticam incitatio.
- (2) directio in polos telluris, et telluris in mundi destinatos terminos verticitas et consistentia.
- (3) variatio, a meridiano deflexio, quem motum nos depravatam dicimus.
- (4) declinatio, infra horizontem poli magnetici descensus.
- (5) motus circularis, seu revolutio.

Of the five he initially listed, three are not basic ones. Variation and declination he later explained as due to irregularities of the surface of the earth, while direction or verticity is the ordering motion that precedes coition.¹²⁴ This leaves only coition and revolution as the basic motions. How these followed from "the congregant nature of the loadstone can be seen when the effusion of forms has been considered."

Coition (he did not take up revolution at this point) differed from that due to other attractions. There are two and only two kinds of bodies that can attract: electric and magnetic.¹²⁵ Gilbert refined his position further by arguing that one does not even have magnetic attraction¹²⁶ but instead the mutual motion to union that he called coition.¹²⁷ In electric attraction, one has an action-passion relation of cause and effect with an external agent and a passive recipient; while in magnetic coition, both bodies act and are acted upon, and both move together.¹²⁸ Instead of an agent and a patient in coition,¹²⁹ one has "contactus." Coition, as the Latin origin of the term denoted, is always a concerted action.¹³⁰ This can be seen from the motions of two loadstones floating on water.¹³¹ The mutual motion in coition was one of the reasons for Gilbert's rejection of the perpetual motion machine of Peregrinus.¹³²

Magnetic coition, unlike electric attraction, cannot be screened.¹³³ Hence it cannot be corporeal for it

¹²³ *Ibid.*, ch. 1, pp. 45-46.

¹²⁴ M: pp. 110, 314.

¹²⁵ M: pp. 82, 105, 170, 172, 217.

¹²⁶ M: p. 98.

¹²⁷ M: pp. 100, 112, 113, 143, 148. It need hardly be pointed out that coitus is not an impersonal term.

¹²⁸ M: p. 110.

¹²⁹ M: p. 110.

¹³⁰ M: pp. 109, 115, 148, 149, 155, 166, 174.

¹³¹ M: pp. 110, 155.

¹³² M: pp. 166, 332. See also footnote 84.

¹³³ M: pp. 90, 106, 107, 108, 113, 132, 135, 136, 158. This is, of course, contrary to modern experience.

travels freely through bodies¹³⁴ and especially magnetic bodies;¹³⁵ one can understand the action of the armature on this basis.¹³⁶ Since coition cannot be prevented by shielding, it must have an immaterial cause.¹³⁷

Yet, unless one has the occult action-at-a-distance, change must be caused by contact forces. Gilbert resolved the paradox of combining contact forces with forces that cannot be shielded, by passing to a higher level of abstraction for the explanation of magnetic phenomena: he saw the contact as that of a form with matter.

Although Gilbert remarked that the cause of magnetic phenomena did not fall within any of the categories of the formal causes of the Aristotelians, he did not renounce for this reason the medieval tradition. Actually there are many similarities between Gilbert's explanation of the loadstone's powers and that of St. Thomas. Magnetic coition is not due to any of the generic or specific forms of the Aristotelian elements, nor is it due to the primary qualities of any of their elements, nor is it due to the celestial "generans" of terrestrial change.¹³⁸

Relictis aliorum opinionibus de magneticis attractione; nunc coitionis illius rationem, et motus illius commoventem naturam docebimus. Cum vero duo sint corporum genera, quae manifestis sensibus nostris motionibus corpora allicere videntur, Electrica et Magnetica; Electrica naturalibus ab humore effluviis; Magnetica formalibus efficientiis, seu potius primariis vigoribus, incitationes faciunt. Forma illa singularis est, et peculiaris, non Peripateticorum causa formalis, et specifica in mixtis, est secunda forma, non generantium corporum propagatrix; sed primorum et praeciporum globorum forma; et partium eorum homogenearum, non corruptarum, propria entitas et existentia, quam nos primariam, et radicalem, et astream appellare possumus formam; non formam primam Aristotelis; sed singularem illam, quae globum suum proprium aeternum et disponit. Talis in singulis globis, Sole, lunas et astris, est una; in terra etiam una, quae vera est illa potentia magnetica, quam nos primarium vigorem appellamus. Quare magnetica natura est telluris propria, eiusque omnibus verioribus partibus, primaria et stupenda ratione, insita; haec nec a caelo toto derivatur procreantive, per sympathiam, per influentiam, aut occultiores qualitates; nec peculiari aliquo astro; est enim suis in tellure magneticus

vigor, sicut in sole et luna suae formae Aristotelicae, lunae, lunaticae ad eius terminos, et formam compositae, solaeque ad solem, sicut magnes ad tellurem, et ad alterum magnetem, secundum naturam sese inclinando et alliciendo. Differendum igitur de tellure quae magnetica, et magnes, tum etiam de partibus eius verioribus, quae magneticae sunt; et quomodo ex coitione differuntur.

Instead, he declared it to be due to a form that is natural and proper to that element that he made the primary component of the earth.¹³⁹

To understand his argument, let us briefly recall the peripatetic theory of the elements. In this philosophy of nature each element or simple body is a combination of a pair of the four primary qualities that informs inchoate matter. These qualities are the instruments of the elemental forms and determine the properties of the element. Thus the element fire is a compound of the qualities hot and dry, and the substantial form of fire acts through these qualities. Similarly for the other elements, earth, water, and air; their forms determine a proper place for each element, and a motion to that place natural to each element.¹⁴⁰

Gilbert had previously declared that the primary substance of the earth is an element. Since it is an element, it has a motion natural to it, and this motion is magnetic coition. As an Aristotelian considered the substantial form of the element, fire, to act through the qualities of hot and dry, and to cause an upward motion; so Gilbert argued that the substantial form of his element, pure loadstone, acts through the magnetic qualities and causes magnetic coition. This motion is due to its primary form, and is natural to the element earth.¹⁴¹ It is instilled in all proper and undegenerate parts of the earth,¹⁴² but in no other element.¹⁴³

To the medieval philosopher, the "generantia" of the occult powers of the loadstone are the heavenly bodies. Gilbert, however, endowed the earth with these heavenly powers which were placed in the earth in the beginning¹⁴⁴ and caused all magnetic materials to conform with it both physically and

¹³⁴ M, p. 105.

¹³⁵ M, pp. 289, 322.

¹³⁶ M, pp. 26, 68, 105, 179, 198, 301, 335, 343. For rotation, see footnote 137.

¹³⁷ M, pp. 67, 71. That each part is informed with the properties of the whole is an argument favoring an atomistic explanation of the nature of this form.

¹³⁸ M, p. 109.

¹³⁹ M, pp. 111, 188.

¹³⁴ M, pp. 106, 107, 108, 114, 134, 136, 140, 162.

¹³⁵ M, pp. 106, 109, 114, 159, 162.

¹³⁶ M, pp. 137-140.

¹³⁷ M, p. 109.

¹³⁸ M, p. 105, and Gilbert, *De magnete*, London, 1600, bk. 2, ch. 4, p. 65.

formally.¹⁴⁵ Such magnetic powers are the property of all parts of the earth;¹⁴⁶ they give the earth its rotating motion¹⁴⁷ and hold the earth together in spite of this motion.¹⁴⁸

Indeed, each of the main stellar bodies, sun, moon, stars, and earth, has such a form or principle unique to itself that causes its parts not only to conform with itself but to revolve.¹⁴⁹ Thus, if one removes a piece of the moon from this body, it will tend to align itself with the moon and then to return to its proper place; and a fragment of the sun would similarly tend to return after proper orientation.¹⁵⁰ Moreover, there is a farther-ranging, though weaker, mutual action of the heavenly bodies so that one has a causal hierarchy of these specific conforming powers. The form of the sun is superior to that of the inferior globes and is responsible for the order and regularity of planetary orbits.¹⁵¹ In like manner, the moon is responsible for the tides of the ocean.¹⁵²

By virtue of the causal hierarchy of forms, the loadstone acquires its magnetic powers from the earth.¹⁵³ As the earth has its natural parts, so has the stone.¹⁵⁴ Although the geometrical center of a terrella is the center of the magnetic forces,¹⁵⁵ objects do not tend to move to the center but to its poles,¹⁵⁶ where the magnetic energy is most conspicuous.¹⁵⁷ However, in a sense, the energy is everywhere equal: the virtue is spread throughout the entire mass of the loadstone,¹⁵⁸ and all the parts direct the forces to the poles.¹⁵⁹ The poles become the "thrones" of the magnetic powers.¹⁶⁰ On the other hand, the directive force is stronger where cohesion is weaker and accordingly, verticity is most prominent at the equator.¹⁶¹

The strength of a loadstone depends upon its shape and mass. A bar magnet has greater powers than a spherical one because it tends to concentrate the magnetic powers more in the ends.¹⁶² For a given purity and shape, the heavier the loadstone, the greater its strength.¹⁶³ A loadstone has a maximum degree of magnetic force that cannot be increased.¹⁶⁴ However, weaker ones can be strengthened by stronger ones.¹⁶⁵ Similarly, the shape and weight of the iron determine the magnetic force in cohesion.¹⁶⁶

The formal forces of a loadstone emanate in all directions from it,¹⁶⁷ but there is a bound to it that Gilbert called the "orbis virtutis."¹⁶⁸ The shape of this "orbis virtutis" is determined by the shape of the stone.¹⁶⁹ This insensible effusion is analogous to the spreading of light that reveals its presence only by opaque bodies.¹⁷⁰ Similarly, the magnetic forms are effused from the stone,¹⁷¹ and can only reveal their presence by cohesion with another loadstone or by "awakening" magnetic bodies within the "orbis virtutis."¹⁷² Unmagnetized iron that comes within the "orbis virtutis" is altered, and the magnetic virtue renews a form that is already potentially in the iron.¹⁷³ The formal energy is drawn not only from the stone but from the iron.¹⁷⁴ This is not generation, or alteration in the sense of a new impressed quality, but alteration in the sense of the entelechy or the activation of a form potentially present.¹⁷⁵ Those bodies

¹⁶² M: pp. 131, 132, 153–158.

¹⁶³ M: pp. 141, 152, 153, 158, 161, 191, 222.

¹⁶⁴ M: p. 146.

¹⁶⁵ M: p. 165.

¹⁶⁶ M: p. 153.

¹⁶⁷ M: pp. 121, 123, 124, 304, 305, 306, 307, 309.

¹⁶⁸ Gilbert defined the *orbis virtutis* in the glossary at the beginning of his treatise as, ". . . totum illud spatium, per quod quaevis magnetis virtus extenditur." This is the core of the difference between electric and magnetic forces. The substantial form of an electric could not be "effused," but was "imprisoned" in matter (as the Neoplatonic soul in the human body); while the primary form of a magnet did not require a material carrier and its effusion was similar to the propagation of a species in light.

¹⁶⁹ M: pp. 124, 150, 151.

¹⁷⁰ M: pp. 123, 307.

¹⁷¹ M: pp. 304–307. See also p. 310, where it is stated that the sun and earth could awaken souls.

¹⁷² M: pp. 101, 110, 112, 123, 148, 149, 304, 305. This awakening of the iron within the "orbis virtutis" is comparable (pp. 216, 350) to the birth of a child under the influence of the stars.

¹⁷³ M: pp. 110, 111, 112, 189, 216, 217. See also footnote 36.

¹⁷⁴ M: p. 106.

¹⁷⁵ M: pp. 106, 109, 110.

¹⁴⁵ M: pp. 67, 105, 179, 183.

¹⁴⁶ M: pp. 101, 105, 217.

¹⁴⁷ M: pp. 179, 304, 305, 311, 322, 326, 328, 330–334, 338–343.

¹⁴⁸ M: pp. 142, 179; see also electric attraction, p. 97.

¹⁴⁹ M: pp. 308, 317–343.

¹⁵⁰ M: pp. 106, 340.

¹⁵¹ M: pp. 308, 309, 311, 330, 333, 344, 347.

¹⁵² M: pp. 136, 334, 345.

¹⁵³ M: pp. 184, 186, 190, 232. This is not quite the same argument as that the powers of the loadstone are identical with those of the earth. See footnote 78.

¹⁵⁴ M: pp. 125, 180.

¹⁵⁵ M: p. 151.

¹⁵⁶ M: pp. 121, 150.

¹⁵⁷ M: pp. 115, 151, 165.

¹⁵⁸ M: pp. 106, 118, 151, 191, 205, 221, 243.

¹⁵⁹ M: pp. 116, 117, 119, 131, 183, 188, 221.

¹⁶⁰ M: p. 31.

¹⁶¹ M: pp. 116, 151, 200.

magnetized by coming within the "orbis virtutis" have in turn an efflux of their own.¹⁷⁶ Iron can also receive verticity directly from the earth without the intervention of an ordinary loadstone.¹⁷⁷ Such verticity can be expelled and annulled by the presence of another loadstone.¹⁷⁸

Although one does not normally find iron to be magnetized, a loadstone always has some magnetism. That two bodies such as iron and loadstone should have different properties is the result of the loss of a form by the iron, but this form is still potentially present in the iron. The iron that has been obtained from an ore has been deformed,¹⁷⁹ for it has been placed "outside its nature" by the fire.¹⁸⁰ The nature has not been removed, since, once the iron has cooled, the confused form can be reformed by a loadstone.¹⁸¹ The latter "awakens" the proper form of iron.¹⁸² After smelting, the magnetized iron may manifest stronger powers than a loadstone of equal weight, but this is because the primary matter of the earth is purer in the iron than in the loadstone.¹⁸³ If fire does not deform a loadstone too much, it can be remagnetized,¹⁸⁴ but a burnt loadstone cannot be reformed.¹⁸⁵ Corruption from external causes may also deform a loadstone or iron so that it can not be magnetized.¹⁸⁶ Bodies mixed with the degenerate substance of the earth or with aqueous humor spoil by contamination with earth, do not show either electric attraction or magnetic coition.¹⁸⁷

In a manner suggestive of Peregrinus, Gilbert wrote that, "magnetic bodies seek formal unity."¹⁸⁸ Thus a dissected loadstone not only tends to come back together, as in the unordered coacervation of electric attraction, but to restore the organization it had before dissection.¹⁸⁹ Accordingly, opposite poles appear on the interfaces of the sections, not "from an opposition" but from "a concordance and a conformance."¹⁹⁰ This ensures that when the

parts are joined together again, they have the same orientation as before. Gilbert compared this power of restoring the original loadstone with that of a plant's vital power under the process of cutting and grafting; the plant can be revived only when the parts are in a certain order.¹⁹¹

A hypothesis similar to that used to explain electric attraction lay beneath the explanation of magnetic coition: that bodies brought into contact will move together. In electric attraction, the contact is material and due to the "spiritus" from the electric body; in magnetic coition, it is formal and depends on the action of a primary form that spreads from a magnetized body to its limit of effusion, the "orbis virtutis." If iron is inside the "orbis virtutis," the two bodies "enter into alliance and are one and the same"¹⁹² for within it "they have absolute continuity, and are joined by reason of their accordance, albeit the bodies themselves be separated."¹⁹³

Gilbert's treatment of coition can be analyzed into the same two steps as can electric attraction. First occurs a contact, which in this case is not physical but formal, and from this initial formal contact follows movement to a more complete unity. Both the contact and the movement to unity are described on the same level of abstraction, instead of on two different levels as in electric attraction. Again one does not find any clear-cut concept of force as a push or pull,¹⁹⁴ but instead, a motion to a formal unity, this time a cooperative motion. The parts of a magnetic body are in greater harmony when they are assembled in a certain pattern and so they move accordingly.

As to the nature of the primary form itself, Gilbert agreed with Thales that it is like a soul,¹⁹⁵ "for the power of self-movement seems to betoken a soul."¹⁹⁶ With Galen and St. Thomas he placed the form of the loadstone superior to that of inanimate matter.¹⁹⁷ In a sense, Gilbert even made it superior to organic matter, for it is incapable of error.¹⁹⁸ Like the soul, the primary form cannot be fragmented; when a loadstone is divided, one does not separate the poles but each part acquires its own poles and an equator

¹⁷⁶ M: pp. 113, 114.

¹⁷⁷ M: pp. 190, 192, 210, 216.

¹⁷⁸ M: p. 209.

¹⁷⁹ M: pp. 107, 110, 111.

¹⁸⁰ M: p. 108.

¹⁸¹ M: pp. 111, 112, 113.

¹⁸² M: pp. 109, 111, 112, 148, 149.

¹⁸³ M: pp. 112, 149.

¹⁸⁴ M: pp. 142, 189.

¹⁸⁵ M: p. 190.

¹⁸⁶ M: pp. 85, 105, 113, 143, 226.

¹⁸⁷ M: p. 84.

¹⁸⁸ M: p. 186.

¹⁸⁹ M: pp. 185, 188. See also footnote 31.

¹⁹⁰ M: pp. 186, 193.

¹⁹¹ M: pp. 199, 200.

¹⁹² M: p. 111.

¹⁹³ M: p. 112.

¹⁹⁴ See, however, M: pp. 112, 113.

¹⁹⁵ M: pp. 109, 312.

¹⁹⁶ M: p. 109.

¹⁹⁷ M: p. 309.

¹⁹⁸ M: pp. 311, 312.

Like the soul, fire does not destroy it.¹⁹⁹ Like the soul of astral bodies, and of the earth itself, it produces complex but regular motions; the motion of two loadstones on water offers such an example.²⁰⁰ Like the soul of a newborn child, whose nature depends on the configuration of the heavens, the properties in the newly awakened iron depend upon its position in the "orbis virtutis."²⁰¹

Whence Gilbert declared:

. . . the earth's magnetic force and the animate form of the globes, that are without senses, but without error . . . exert an unending action, quick, definite, constant, directive, motive, imperant, harmonious through the whole mass of matter; thereby are the generation and the ultimate decay of all things on the superficies propagated.²⁰² The bodies of the globes . . . to the end that they might be in themselves, and in their nature endure, had need of souls to be conjoined to them, for else there were neither life, nor prime act, nor movement, nor union, nor order, nor coherence, nor *contactus*, nor *sympathia*, nor any generation nor alteration of seasons, and no propagation; but all were in confusion . . .²⁰³ Wherefore, not with reason, Thales . . . declares the loadstone to be animate, a part of the animate mother earth and her beloved offspring.²⁰⁴

Gilbert ended book 5 of his treatise on the magnet with a persuasive plea for his magnetic philosophy of the cosmos, yet his conceptual scheme was not too successful an induction in the eyes of his contemporaries. In particular the man from whom the Royal Society took the inspiration for their motto, "Nullius in verba," did not value his magnetic philosophy very highly. Whether Francis Bacon was alluding to Gilbert when he expounded his parable of the spider and the ant²⁰⁵ is not explicit, but he certainly had him in mind when he wrote of the Idols of the Cave and the Idols of the Theater.²⁰⁶

Few of the subsequent experimenters and writers on magnetism turned to Gilbert's work to explain the effects they discussed. Although both his countrymen Sir Thomas Browne²⁰⁷ and Robert Boyle²⁰⁸ de-

scribed a number of the experiments already described by Gilbert and even used phrases similar to his in describing them, they tended to ignore Gilbert and his explanation of them. Instead, both turned to an explanation based upon magnetic effluvia or corpuseles. The only direct continuation of Gilbert's *De magnete* was the *Philosophia magnetica* of Nicolaus Cabeus.²⁰⁹ The latter sought to bring Gilbert's explanation of magnetism more directly into the fold of medieval substantial forms.

However, Gilbert's efforts towards a magnetic philosophy did find approval in two of the men that made the seventeenth century scientific revolution. While Galileo Galilei²¹⁰ was critical of Gilbert's arguments as being unnecessarily loose, he nevertheless saw in them some support for the Copernican world-system. Johannes Kepler²¹¹ found in Gilbert's explanation of the loadstone-earth a possible physical framework for his own investigations on planetary motions.

Yet Galileo and Kepler had moved beyond Gilbert's world of intellectual experience. They were no longer concerned with determining the nature of material things in order to explain their qualities. Instead, they had passed into the realm of the mathematical relations of kinematics; quantitative law had replaced qualitative experience of cause and effect. Gilbert had some intimations of the former, but he was primarily concerned with explaining magnetism in terms of substance and attribute. He had to ascertain the nature of the loadstone and of the earth in order to explain their properties and their motions. He even went further and explained the nature of the form of the loadstone.

His method of determining the nature of a substance was a rather primitive one—it was not by a process of induction and deduction, nor by synthesis and analysis, nor by "resolutio" and "compositio," but by the use of analogies. He compared the natural history of metals and rocks with that of plants, and gave the two former the same kind of principle as the last. He determined the nature of the entity behind electric attraction by finding that such attractions could be screened, and hence it had to be corporeal. After comparing this "corporeal" attraction with that of

¹⁹⁹ M: p. 108.

²⁰⁰ M: p. 110.

²⁰¹ M: p. 216.

²⁰² M: p. 311.

²⁰³ M: pp. 310, 311.

²⁰⁴ M: p. 312.

²⁰⁵ Francis Bacon, *op. cit.* (footnote 42), vol. 1, *Novum organum*, bk. 1, ch. 95, p. 306.

²⁰⁶ *Ibid.*, ch. 54 and ch. 64 (pp. 259 and 267).

²⁰⁷ Sir Thomas Browne, *Pseudodoxia epidemica*, ed. 3, London, 1658, bk. 2, ch. 2, 3, 4.

²⁰⁸ Robert Boyle, *Experiments and notes about the mechanical production of magnetism*, London, 1676.

²⁰⁹ Nicolaus Cabeus, *Philosophia magnetica*, Ferrara, 1629.

²¹⁰ Galileo Galilei, *Dialogue on the great world systems*, in the translation of E. Salusbury, edited and corrected by G. de Santillana, University of Chicago Press, 1953, pp. 409–423.

²¹¹ Cassirer, *op. cit.* (footnote 3), vol. 1, p. 359–367.

the surface forces of a fluid, he concluded that the entity was a subtle fluid. He determined the nature of the entity behind magnetic cohesion by (incorrectly) finding that it cannot be screened, and hence the cause had to be a formal one. Since both stars and the loadstone can carry out regular motions, and stars had souls, the form of the loadstone had to be a soul. The method of analogy was used again in his comparison of the properties of a magnetized needle placed over a terrella with the properties of a compass placed over the earth, whence he concluded the earth to be a giant loadstone. Since the earth resembled the other celestial globes, it had to have, the circular inertia of these globes.²¹² As for his magnetic experiments to show physically that the earth moved, and his unbridled speculations on the "animae" of the celestial globes, one is inclined to agree with Bacon's estimate of his magnetic philosophy.

One might consider Gilbert's book as a Renaissance recasting of Aristotle's *De caelo* with the earth in the role of a heavenly body. So it might well be, for Gilbert was still concerned with distinguishing the nature of the heavenly body, earth, that caused the coitional and revolving motions, from those natures for which up and down, and coaccervation were the natural motions. Because the natural motions were different, the natures had to be different, and these different natures led to a universe and a concept of space neither of which were Aristotelian. One no longer had a central reference point for absolute space; there was no "motor essentialis" focused upon the earth but one had only the mutual motion of the heavenly bodies. The natural distinction between heaven and earth was gone, for the earth was no longer an inert recipient but a source of wonder, and so the stage was set for the universe

²¹² Because the earth has the same nature as a celestial globe, its revolution and circular inertia require no more explanation than those of any other heavenly body.

of Giordano Bruno. The Aristotelian philosophy of nature was used to justify a new cosmology, but there was no break with the past such as one finds in Galileo and Kepler. Instead he followed the chimera of the world organism, as Paracelsus had, and of the world soul, as Bruno had. Consequently Gilbert's physiology did not enter into the main stream of science.

Yet this is not to deny Gilbert's services to natural philosophy. Although not all of his experimental distinction between electric and magnetic forces has been retained, still, some of it has. His "orbis virtutis" was to become a field of force, and his class of electrics, insulators of electricity. His practice of aiming a loadstone was to be of considerable importance in the period before the invention of the electromagnet. His limited recognition of the mutual nature of forces and their quantitative basis in mass was ultimately to appear in Newton's second and third laws of motion. In spite of the weaknesses of the method of analogy, Gilbert's experimental model of the terrella to interpret the earth's magnetism was as much a contribution to scientific method as to the theory of magnetism.

Consequently, in spite of an explanation of electricity and magnetism that one would be amused to find in a textbook today, we can still read his *De magnetibus* with interest and profit. But more important than his scientific speculations, is the insight he can give us into a Renaissance philosophy of nature and its relation to medieval thought. One does not find in *De magnetibus* a prototype of modern physical science in the same sense one can in the writings of Galileo and Kepler. Instead one finds here a full-fledged example of an earlier kind of science, and this is Gilbert's main value to the historian today.

²¹³ One wonders if Bruno might not have been another of the stimuli for Gilbert. The latter's interest in magnetism began shortly before Bruno visited England and lectured on his interpretation of the Copernican theory.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 9

CONESTOGA WAGONS IN
BRADDOCK'S CAMPAIGN, 1755

Don H. Berkbile

CONESTOGA WAGONS IN BRADDOCK'S CAMPAIGN, 1755

More than 200 years have passed since the Pennsylvania farm wagon, the ancestral form of the Conestoga wagon, first won attention through military service in the French and Indian War. These early wagons, while not generally so well known, were the forerunners of the more popular Conestoga freighter of the post-Revolutionary period and also of the swaying, jolting prairie schooners that more recently carried hopeful immigrants to the western territories.

THE AUTHOR: Don H. Berkebile is on the exhibits staff of the Smithsonian Institution's United States National Museum.

IN A SPEECH to the Pennsylvania Assembly on December 19, 1754, Governor Morris suggested a law that would "settle and establish the wages" to be paid for the use of the wagons and horses which soon were to be pressed into military service for the expedition against Fort DuQuesne.¹ His subsequent remarks on the subject were all too indicative of the difficulties which were later to arise. The Assembly however, neglected to pass such an act, and the Maryland and Virginia Assemblies were equally lax in making provision for General Braddock's transportation.

Sir John St. Clair had told Braddock, shortly after his arrival in the colonies in late February 1755, "of a great number of Dutch settlers, at the foot of a mountain called the Blue Ridge, who would undertake to carry by the hundred the provisions and stores" St. Clair was confident he could have 200 wagons and 1,500 pack horses at Fort Cumberland by early May. On April 21 Braddock reached Frederick, in Maryland. There he found that only

25 wagons had come in and several of these were unserviceable. Furiously the General swore that the expedition was at an end. At this point, Benjamin Franklin, who was in Frederick to placate the wrath of Braddock and St. Clair against the Pennsylvanians, commented on the advantages the expedition might have gained had it landed in Philadelphia instead of Alexandria,³ and pointed out that in eastern Pennsylvania every farmer had a wagon. Braddock then suggested that Franklin try to raise the needed 150 wagons and the 1,500 pack horses. Asking that the terms to be offered be first drawn up, Franklin agreed to the undertaking and was accordingly commissioned. On his return to Pennsylvania, Franklin published an advertisement at Lancaster on April 26, setting forth the terms offered (the full text of this advertisement is found in Franklin's autobiography).

Although eventually successful, Franklin was beset by many difficulties in collecting the wagons. Farmers argued that they could not spare teams from the work of their farms. Others were not satisfied with the terms offered. Furthermore, the Quaker-controlled Assembly had little interest in the war and did nothing

¹ *Pennsylvania Archives*, ser. 8, vol. 5, Morris to the House, Dec. 19, 1754.

² Robert Orme's Journal, in Winthrop Sargent, *The history of an expedition against Fort DuQuesne*, p. 288, Philadelphia, 1855.

³ Benjamin Franklin, *Autobiography*, p. 166, New York, 1939.



FIGURE 1. BRADDOCK'S ROUTE in the campaign of 1755. The solid line approximates the present U.S. route 40. From Windthrop Sargent, *The history of a expedition against Fort Duquesne*. Philadelphia, 1755.

ing to regulate the hire of wagons, in spite of the repeated pleas of the governor. Franklin published new advertisements more strongly worded than the first, threatening an impress of wagons and drivers if better cooperation could not be had.⁴ Finally the governor found it necessary to issue threatening warrants to the magistrates of four of the more reluctant counties. This action brought in the wagons but caused new difficulties to arise, for in order to prevent trouble the townships had contributed, in addition to the fifteen shillings per day offered in Franklin's terms, from five to fifteen pounds to each owner who would hire out his wagon.

This practice caused others to demand more for their services. Governor Morris wrote to Richard Peters that he was "preparing to send sixty waggon loads of oats and corn from hence (Philadelphia), for

which I am sorry to say, that I shall be obliged to give more for the transporting of it, than the thing is worth, such advantages are taken by the people of the Public wants. . . ."⁵ Two weeks later Edward Shippen, explaining the teamsters side of the argument, told how they had to pay ferrriage at the Susquehanna and make the return trip with empty wagons.⁶ It would be well to mention here that not all of the wagons were to accompany the expedition; many were to transport supplies only to Conococheague⁷ or to Wills Creek, and it was the owners of these wagons who, since they did not feel bound by the same terms offered the 150 accompanying the expedition, most often took advantage of the situation. In addition, wagons were needed to supply Colonel James Bird and his party, who were building the Pennsylvania

⁴ *Pennsylvania Archives*, ser. 1, vol. 2, pp. 295-96. Franklin suggested that St. Clair, with a body of troops, would probably enter Pennsylvania and take what he wanted, if it could not be obtained otherwise.

⁵ *Ibid.*, ser. 1, vol. 2, Morris to Peters, May 17, 1755.

⁶ *Ibid.*, Shippen to Morris, June 15, 1755.

⁷ The modern spelling is given above. A spelling of *Conococheague* was common in 1755, among other things, in the *Journal* of J. C. Cook, etc.



Figure 2. STRAKES BEFORE BEING COMPLETELY UNearthED. Strakes are sections of wagon tire, equal in number to the felloes of the wheel.

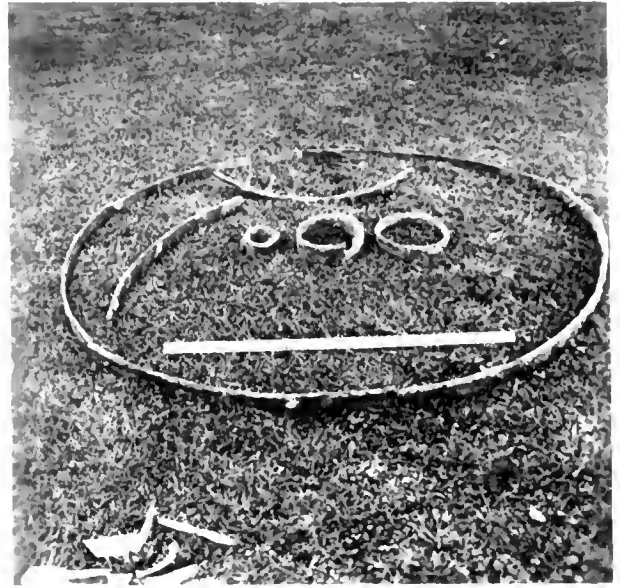


Figure 3.— SIX STRAKS ARRANGED IN A CIRCLE, as they would encompass a 12-spoke wheel. In the center are two extra strakes, two hub bands, and a hub boxing (the smaller ring).

road from Shippensburg to the forks of the Youghiogheny,⁸ where it was to meet with Braddock's road. When word came back to the settlements that Indians had killed several of Burd's wagoners, recruiting became still more difficult. The alarm became so great that the road builders threatened to leave if protection was not sent them. Accordingly, Captain Hogg was sent with his company from Braddock's army to cover them.⁹

The farm wagons used in these operations were often referred to as Conestoga wagons.¹⁰ This term was apparently in general use at least as early as 1750, when the term "Dutch Wagon" was also used in referring to this particular type of vehicle.¹¹ The

⁸This is the modern spelling. Among those used in 1755 were Yoxhio Geni and Ohiogany.

⁹*Pennsylvania Archives*, ser. 1, vol. 2, Shippen to Allen, June 30, 1755. Also, Orme's Journal, in Sargent, *op.cit.* (footnote 2), p. 329.

¹⁰Originally spelled Conestogoe. The first known reference to a Conestoga wagon appears under date of 1717 in James Logan's "Account Book, 1712-1719," the manuscript original of which is in the Historical Society of Pennsylvania, in Philadelphia. It is likely that the reference was only to a wagon from Conestogoe, and not to a definite type of vehicle.

¹¹The term seems to have been in common use by 1750 since a tavern in Philadelphia, called "The Sign of the Conestoga Wagon," was mentioned in an advertisement in the *Pennsylvania Gazette*, February 5, 1750, but another advertisement, (*ibid.*, February 12, 1750), in referring to what was apparently the same establishment, uses the term "Dutch Wagon."

Conestoga, deriving its name from the Conestoga valley near Lancaster, was apparently a Pennsylvania adaptation of the English wagon.¹² Unfortunately there are no existing specimens of early wagons of whose age we can be certain, and the few wagon fragments that have been unearthed are insufficient to justify any conclusions. A number of strakes¹³ were found in Edmund's Swamp (figs. 2-5), on the route of the Forbes expedition in 1758. These indicate a wheel diameter of 64 inches and a tire 2 inches wide.¹⁴ The 2-inch tires are undoubtedly relics of a farmer's wagon, since the various military vehicles had tires no less than 3 inches and often on the heavier types 4 inches wide. The use of strakes also

¹²It is not certain at this time whether English or German styles influenced the Conestoga wagon most. Judging from some early English wagons still in existence, it would appear that some of these lines were followed. Even today some farmers, and those who have been close to the wagon and its use, frequently refer to the Conestoga type as "English wagons."

¹³Strakes are sections of wagon tire, equal in number to the felloes of a wheel. On early vehicles the tires were put on in sections and spiked in place. Later, one endless tire was "sweated" on, by being heated, fitted on the wheel, and cooled in place.

¹⁴Found in 1953 by the Field Corps for Historical Research, these strakes are obviously from rear wheels. Though dimensions were by no means standardized, front wheels were always smaller, so that in turning the wagon the tires would be less likely to rub the sides of the wagon box.



Figure 4. A STRAKL, SHOWING SPIKES. On early vehicles the tires were put on in sections and spiked in place. Later one endless tire was "sweated" on by being heated to expand it, fitted on the wheel, and cooled in place.

indicates that these early wagons had no brakes such as the large Conestogas of a later era had.¹⁵ From all indications it would appear that these early farm wagons differed from the larger freighters of the 1790's and were probably similar to the lighter, farm-type Conestogas of the 19th century. Farm wagons are somewhat smaller than road wagons, generally bear less ornamentation and lack the more graceful lines of the latter.

Contemporary letters and newspaper advertisements attest to the fact that farm wagons were the type used by Braddock. For example, Franklin's advertisement in the *Pennsylvania Gazette* on May 22, 1755, noted that "several Neighbors may conveniently join in fitting out a Waggon, as was lately done in the Back Counties." Had these wagon owners been other than farmers of poor means, such a notation would have been unnecessary. In another communication to the inhabitants of Lancaster, York, and Cumberland Counties Franklin said, "three or four of such as cannot separately spare from the business of their Plantations a Wagon and four Horses and a Driver, may do it together, one furnishing the Waggon, another one or two

¹⁵ Strakes were spiked onto the wheel with large square headed nails, as indicated in figure 3, and a brake shoe would have been rapidly torn to pieces by rubbing against them.



Figure 5. BANDS AND HUB BOXING, shown in figure 3. These and the strakes shown in figures 2-4, parts of an old Pennsylvania farm wagon, were found in Edmunds Swamp, Pennsylvania, along the route of the Forbes Expedition of 1758.

Horses, and another the Driver, and divide the pay proportionably between you."¹⁶ Many letters describe the owners of the wagons with such phrases as "the Poorer sort," and "narrow circumstances of the Country People, who are to supply the waggon. . . ."¹⁷ These remarks indicate that farm wagons were used and suggest that the larger Conestogas, such as were driven by professional teamsters, probably had not yet been developed.

That Braddock's wagons were small is evidenced by the loads carried. Governor Morris seems to indicate loads as small as thirty-five bushels when he sent a dispatch to Braddock informing him that he had bought "one thousand bushels of Oats and one thousand bushels of Indian Corn in this town [Philadelphia], and have directed sixty waggons to be taken up."¹⁸ This is substantiated by a remark in Captain Orme's journal, in which he states that "The loads of all waggons were to be reduced to fourteen hundred weight. . . ." Under the same date, June 11, he indicated that the farmers wagons were smaller than the English wagons when he wrote "all the King's waggons were also sent back to the

¹⁶ *Pennsylvania Archives*, ser. 1, vol. 2, pp. 295-96.

¹⁷ *Ibid.*, ser. 1, vol. 2, Shippen to Morris, February 17, 1755, and ser. 3, vol. 2, Denny to Amherst, March 3, 1755.

¹⁸ *Ibid.*, ser. 1, vol. 2, Morris to Braddock, June 4, 1755.



Figure 6. — RESTORED FREIGHT-CARRYING CONESTOGA WAGON, about 1830, in the collection of the author. The tongue is not full length. (Photo by the author.)

fort, they being too heavy and requiring large horses for the shafts. . . .”¹⁹ Another communication from Morris states that he “dispatched fifty-two waggons from this town, each carrying fifty bushels of grain, one half oats the other Indian Corn.”²⁰ This makes a load of about 2,200 pounds,²¹ quite in agreement with the statement in the *Gentlemen’s Magazine* of August 1755, that loads were commonly around one ton. A load of one ton is small in comparison to those hauled by later wagons that sometimes carried as much as five or even six tons.

An approximate description of the size of the wagon, taken from the earliest existing specimens of the same type shows a bed about 12 feet long on the bottom and 14 feet on the top. Depth of the bed ran about

¹⁹ Orme’s Journal, in Sargent, *op. cit.* (footnote 2), pp. 331–32. English wagons were equipped with pairs of shafts, similar to those of a spring wagon or buggy of recent times. Wagon shafts were, however, much heavier than the latter.

²⁰ *Pennsylvania Archives*, ser. 4, vol. 2, Morris to Braddock, June 12, 1755.

²¹ R. Moore, *The universal assistant*, p. 205, New York, n. d. The weight of corn is given at 56 pounds per bushel, and oats at 32 pounds per bushel.

32 inches and the width was approximately 42 to 46 inches. Though there was little standardization in most features, eight bows usually supported the dull white homespun cover. The diameter of the front wheels varied from 40 to 45 inches, while the rear wheels ran 10 to 20 inches larger.²²

For a 1759 expedition it was recommended that wagon accessories include drag chains, grass cutting knives, axes, shovels, tar buckets (for lubricating axles), jacks, hobbles, and extra sets of such items as clouts (axle-bearing plates), nails, horseshoes, hames, lynch pins, and hamestrings.²³ It is doubtful if many teamsters in the 1755 expedition had so complete a selection of equipment; campaign experience in the mountains of western Pennsylvania was necessary to

²² One light wagon of about 1800 had smaller wheels, the front being 37 inches and the rear 49 inches in diameter.

²³ *Pennsylvania Archives*, ser. 1, vol. 3, advertisement of General Stanwix for wagons, May 4, 1759.

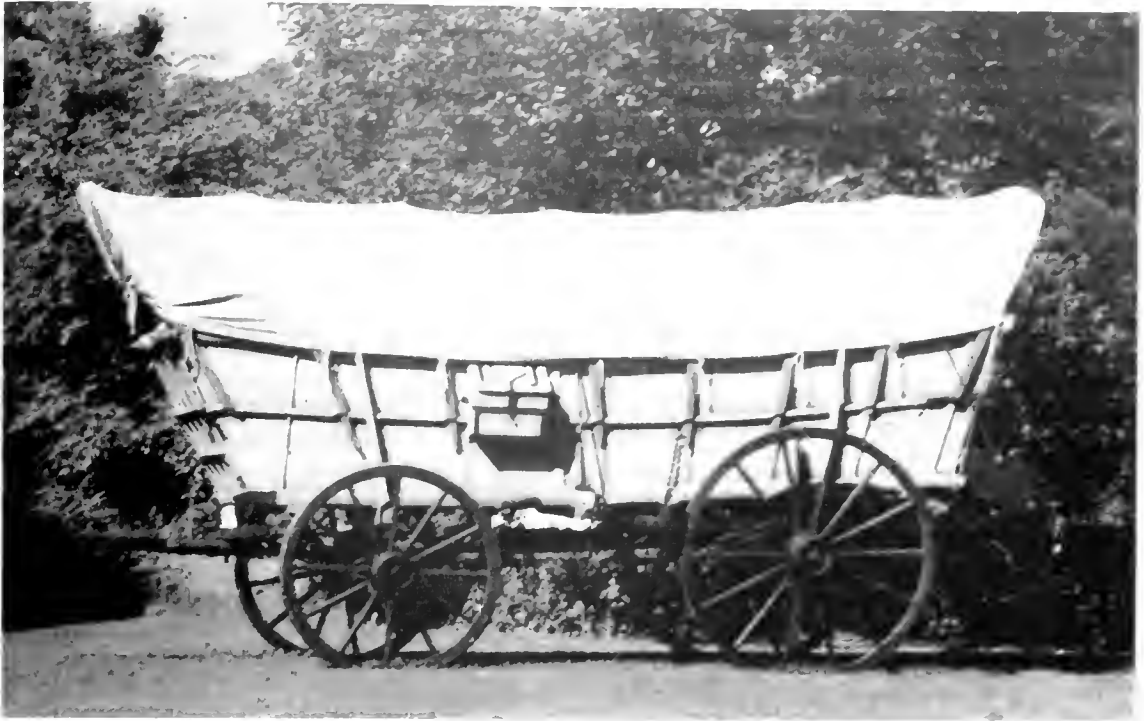


Figure 7. FARM-TYPE CONESTOGA WAGON, about 1850 in the collection of the author. The tongue is not full length. (Photo by the author.)

convince them of this necessity. There is no evidence that the hame bells later to be found on professional teams were used at this early date. The advertisement²⁴ that was circulated for the 1759 expedition mentions a “slip bell . . . for each horse” among the items necessary on an expedition, so it is possible that some drivers of the 1755 expedition may have used a single bell on each horse, as was the custom with pack horses. These bells, kept stuffed during the day, were unstuffed at night when the horses were put out to forage in the woods so that they might be more easily found in the morning. Orme mentions no bells, although he writes of other methods used to avoid losing horses at night.

Early in May detachments of the Army began to arrive at Wills Creek. During the advance to Wills Creek the lack of transportation had been keenly felt. Wagons had been forced to shuttle back and forth between camps in order to keep all stores and provisions moving forward.²⁵ By the latter part of May the Pennsylvania wagons were coming in; about 90 arrived on May 20. That same night 30 wagons had to be sent on to Winchester to bring up to Wills Creek the provisions which could not be brought earlier for

lack of wagons. Also, 300 of the pack horses had to be sent back to Conococheague, through which the wagons had just passed, to bring up the flour which agent Cresap of that place had through neglect or intention failed to forward in the wagons as he had been directed. On May 27, 100 wagons were on hand, with some still coming in.²⁶ According to the accounts of the commission later appointed to settle wagoner’s claims, 146 wagons with teams, and about 510 pack horses were provided by Pennsylvanians to accompany the army.²⁷

As the army prepared to move from Fort Cumberland, William Shirley, secretary to General Braddock, advised Governor Morris “we move from this place with 200 Waggons.”²⁸ In many communications such as this there appears a certain looseness in reporting numbers in round figures, and also in using the words “waggons” or “carriages” in an all in-

²⁴ Seaman’s Journal, in Sargent, *op. cit.* (footnote 2), p. 380.

²⁵ Lewis Bud Walker, ed., *The settlement of the waggons*, 1766, 1899.

²⁶ *Pennsylvania Archives*, ser. 1, vol. 2, Shirley to Morris, June 7, 1755.

²⁴ *Ibid.*

²⁵ Will H. Lowdermilk, *Edward Braddock’s military books*, Cumberland, 1880, p. 25.

clusive sense. It is obvious that such figures must often have included any wheeled vehicle, and sometimes even the gun carriages. Thus the figure 200 undoubtedly includes 145 Pennsylvania wagons,²⁹ plus a number of British Army wagons, tumbrils, and perhaps gun carriages. By Braddock's own count he had about 40 wagons over and above those he got from Pennsylvania;³⁰ how many of these were British wagons, tumbrils, or possibly a few of the wagons Gage had impressed on his march to Wills Creek, is unknown.³¹

From the beginning of the march, the roads were a challenge, for both Braddock's and Burd's roads presented what appeared to be unsurmountable obstacles. An examination of the terrain over which they had to pass causes far greater respect for these road builders and drivers than is usually accorded them. Orme again comes forward with the picture of their labors. Major Chapman had marched from Wills Creek at daybreak of May 30,³² with the advance unit of the army and, says Orme, "it was night before the whole baggage had got over a mountain about two miles from the camp. The ascent and descent were almost a perpendicular rock; three waggons were entirely destroyed, which were replaced from the camp; and many more were extremely shattered."³³ Braddock went out from the fort and reconnoitered this section of road. Although 300 men and the company of miners had been working on the road for several days, the General "thought it impassable by howitzers," and was about to put another 300 to work when Lt. Spendelowe of the detachment of seamen informed him of an easier route he had found.³⁴ Thus the remainder of the wagons were spared the trip over the "perpendicular rock."

²⁹ Walker, *op. cit.* (footnote 27), p. 20. Of the 146 wagons, one was apparently unserviceable by the time it reached Wills Creek. Its owner was paid only for his services and the use of his team.

³⁰ Orme's Journal, in Sargent, *op. cit.* (footnote 2), p. 321.

³¹ *Ibid.*, p. 312.

³² *Ibid.*, p. 323. There is some question here whether the incident reported occurred near Wills Creek, or on June 15 in the Allegheny Mountains. Orme reports two such incidents with identical figures and nearly identical language. Perhaps he was confusing the two places.

³³ *Ibid.*, p. 334. When wagons were damaged on the march, and repair was impossible, the load was divided among the other wagons and the unserviceable wagon abandoned.

³⁴ *Ibid.*, p. 324 (see also Seaman's Journal, in Sargent, *op. cit.* (footnote 2), p. 381). A detachment of 30 seamen and several officers had been detached from the fleet and assigned to the expedition to offer assistance in rigging cordages, in the event that the erection of bridges would be necessary.

In addition to these difficulties of baggage movement, there was the unavoidable peril of losing horses, particularly at night. Orme gives the following description of the situation:³⁵

Most of the horses which brought up the train were either lost, or carried home by their owners, the nature of the country making it impossible to avoid this fatal inconvenience, the whole being a continual forest for several hundred miles without inclosures or bounds by which horses can be secured: they must be turned into the woods for their subsistence, and feed upon leaves and young shoots of trees. Many projects, such as belts, hobbles, &c., were tried, but none of these were a security against the wildness of the country and the knavery of the people we were obliged to employ: by these means we lost our horses almost as fast as we could collect them, and those which remained grew very weak, so we found ourselves every day less able to undertake the extra-ordinary march we were to perform.

Braddock soon appointed a Wagon Master General, and under him wagon masters, horse masters, and drovers. By his order, horses were to be mustered both morning and evening. When the men made camp, the wagons were to be drawn up in a single line along the road, with an interval between companies. The horses were then turned into the woods to feed, surrounded by a line of sentinels who were not to permit any horses to pass them.

By June 16, when the first brigade reached Little Meadows, Braddock realized that the advance of his column was being retarded and his troops weakened by the number of wagons in his train.³⁶ Washington, who had profited from his 1754 experiences in Pennsylvania, previously had recommended that Braddock use more pack horses and fewer wagons.³⁷ It became obvious that wagons, while ordinarily superior to pack animals, lost this advantage if the roads were not sufficiently opened to admit their easy passage. In view of this, Braddock decided to advance from Little Meadows with a picked detachment of 1,300 men and a minimum of wagons, about 30 in number, and to

³⁵ *Ibid.*, p. 313.

³⁶ *Ibid.*, p. 334 (see also Seaman's Journal, in Sargent, *op. cit.* (footnote 2), p. 383). At times it was necessary for half the troops to ground their arms and assist in moving the wagons up or down grades.

³⁷ Douglas S. Freeman, *George Washington*, vol. 1, p. 140, New York, 1949. Washington had written his brother John on June 14 and given his opinion that they should "retrench the wagons and increase the number of bat horses."

leave the heavier baggage with 84 wagons in charge of Colonel Dunbar and his 850 men.³⁸ Prior to this reorganization at Little Meadows, four horse teams had been used in accordance with the terms of Franklin's advertisements. Now, however, the advance unit of the army marched with six horses to a wagon,³⁹ a change necessitated equally by the rugged terrain and the hastily constructed roads with which they were forced to contend, and by the poor condition of the horses.⁴⁰

While this lightened column moved forward more rapidly, the mountainous and rocky roads continued to impede the progress of the army. On the morning of June 25 so steep a grade was encountered that the men were obliged to ease the carriages down with tackles. Throughout the remainder of June and the early part of July the column was so retarded by the road conditions that only a few miles could be covered each day.⁴¹ By July 4 the country had become less difficult and the army was able to add a few more miles to the daily march. At one o'clock on the afternoon of July 9 this small train of wagons moved over the second ford of the Monongahela between the troops of the 44th and 48th regiments. A short time later the unfortunate expedition met defeat for all its efforts. As the battle drew to a close, many of the surviving troops began to gather around the wagons. This drew heavier fire on the wagons and at this point, said Franklin, "the wagoners took each a horse out of his team and scamper'd."⁴²

³⁸ Sargent, *op. cit.* (footnote 2), p. 203. Wagons apparently carried only artillery stores and other ammunition with the advance detachment. All provisions were carried on pack horses.

³⁹ Orme's Journal, in Sargent, *op. cit.* (footnote 2), p. 336.

⁴⁰ *Ibid.*, p. 332. Orme said the condition of the army was such that they could not reject any horses, a situation that was used to advantage by many contractors. He refers to the horses as "The offcasts of Indian traders, and scarce able to stand under one hundred weight." By contract they were to have carried twice that load.

⁴¹ *Ibid.*, pp. 342-346. On June 26, due to the "extreme badness of the road," the army covered 4 miles; on June 27, 6 miles; June 28, 5 miles; and on June 30 passage over a mountain reduced the day's march to 2 miles.

⁴² Walker, *op. cit.* (footnote 27). It is interesting to note in the Waggoners' Accounts which of the teamsters apparently took a horse and "scamper'd." On the accounts of a number of them is entered the remark "to a horse returned," indicating that they were first credited for the loss of wagon and team, but the value of one horse was deducted in the final settlement, the one horse having arrived safely back at Wills Creek, in company, no doubt, with its anxious driver.

As evening drew on the wounded Braddock sent Washington back to Dunbar's Camp, nearly 45 miles behind, to order wagons forward with provisions and hospital stores and to transport the wounded back to Wills Creek. A number of these wagons met the retreating army on July 11, at Gist's Plantation; then, after wounds were dressed, they returned to Dunbar's Camp. There most of the wagons were gathered with the stores and burned in order to keep them from the hands of the enemy. The survivors continued their retreat, accompanied by a few of the wagons loaded with wounded comrades.

The number of Pennsylvania wagons that arrived back at Wills Creek has not been definitely established. For the service of their wagons, 50 owners received payment for a period greater than the 51 days, but of these, only 10 were paid for services beyond what appears to be July 20.⁴³ Only the wagon of William Douglas, out of 146 wagons involved, seems to have survived the campaign intact.⁴⁴ Inasmuch as the other owners were reimbursed for the loss of their wagons, it is likely that those few that arrived back at Fort Cumberland were so badly damaged as to render them unserviceable, and therefore not worth driving back to eastern Pennsylvania.

Seven criticisms were made of Braddock's advance to the forks of the Ohio. Of these seven, six, in varying degrees, concern transportation.⁴⁵ In choosing Alexandria to land his troops he put himself more distant from the needed wagons; his horses were too few and too weak to bear the burden of all the supplies on the entire march, without depots having first been established at the various camps along the line of march; his troops were delayed by the progress of the wagons and by the necessity of their having to help with the wagons; the roads were inadequate in many places for

⁴³ A true picture is not presented here, since the accounts, except for a few cases, do not contain either the number of days for which the owners were paid or the dates of service. Only the amounts paid are given, which, if broken down at 15 shillings per day, at first would appear to indicate the last date of service. However, since it is not known which, if any, of these wagons went to Winchester before the march, no accurate conclusions can be reached. There can be little doubt that the few wagons that reached Wills Creek late in July were among the 50.

⁴⁴ Walker, *op. cit.* (footnote 27), p. 24. Douglas was not reimbursed for the loss of his wagon and was paid for an additional 55 days of service at a slightly reduced rate, due to the loss of one horse.

⁴⁵ Freeman, *op. cit.* (footnote 37), vol. 2, p. 84.

the excessively heavy artillery and the wagons; the pack horses were weakened by the extra service they were required to perform; and due to his lack of horses, Dunbar had been left too far behind.¹⁶ While other factors contributed to the outcome of the expedition, many of the officers learned, as had

Washington in 1754, the importance of proper transportation.

¹⁶ *Ibid.*, p. 90. As wagons had been shuttled back in April, it was also necessary for Dunbar to shuttle horses, drawing up the first of his wagons one day and returning with his few horses on the following day to bring up the balance of the wagons.

THE CONESTOGA WAGON AND THE PRAIRIE SCHOONER

Styles in farm equipment change slowly, and it is probable that the farm-type Conestoga wagon of about 1850 shown in figure 7 is similar in many respects to the Pennsylvania wagons used by Braddock a century earlier. The prairie schooner, too, bore many of the characteristics of these early farm wagons. It was about the same length as the Conestoga wagon, but the lines of the bed were straight rather than curved and the bows supporting the cloth cover were upright rather than slanting fore and aft. Also, the prairie schooner had a seat where the driver, or at least his family, could ride during the seemingly endless days of the journey.

In this respect the prairie schooner differed not only from the early farm wagons, but also from the large freighting Conestogas, like that in figure 6, which dates from about 1830. In

the years following the Revolution and before the coming of the railroad these freighters were used to carry all types of merchandise to Pittsburgh from Philadelphia by way of present route U.S. 30 and from Baltimore by way of present route U.S. 40.

The freighting Conestoga had no inside seats, and the teamster, when not walking by his team, either rode the left wheel horse or the "lazy board" projecting from the left side of the wagon, just in front of the rear wheel. It is distinguished by its distinctive, overhanging end bows, from which swept down the characteristic homespun cover, and by its lines, which are longer and more graceful than those of either the later prairie schooner or the earlier Pennsylvania farm wagon.

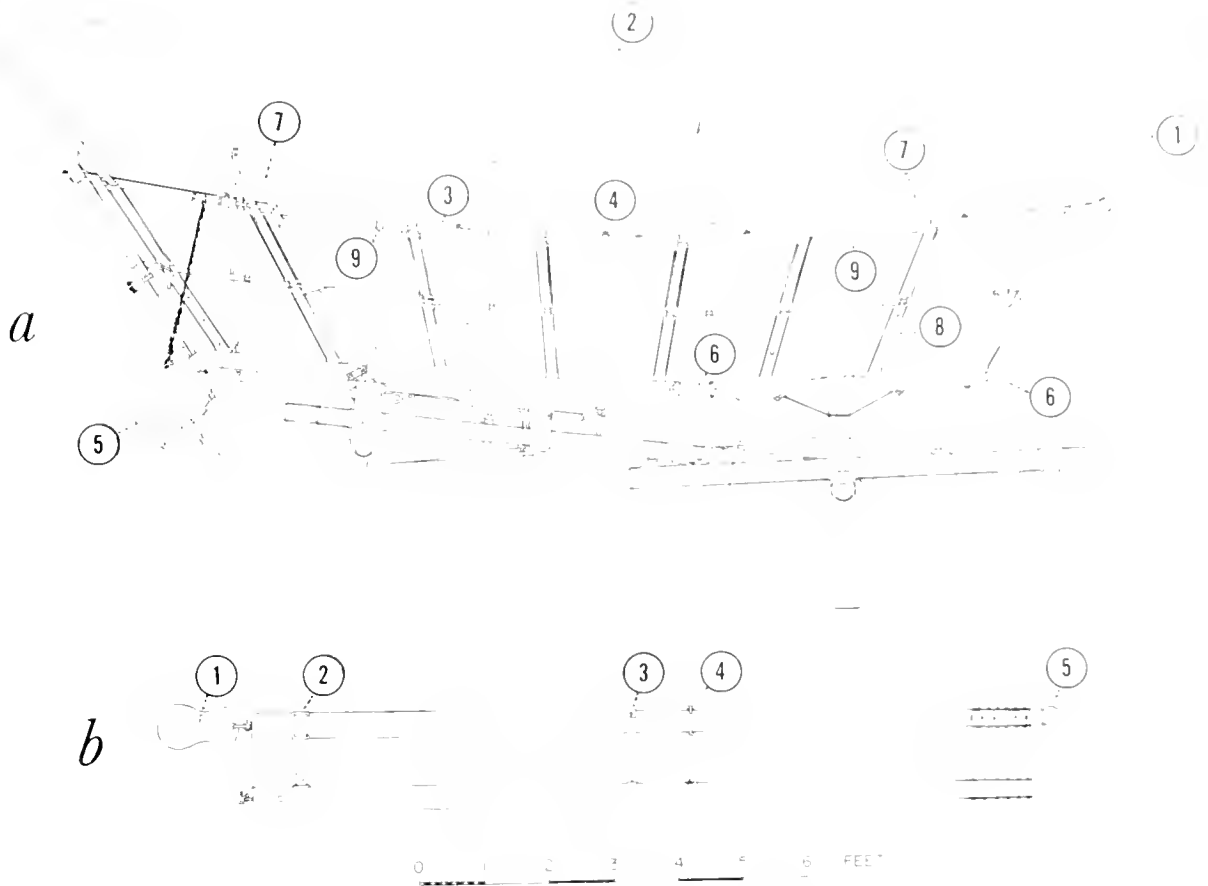


Figure 8. FREIGHT-CARRYING WAGON OF THE PERIOD 1800-1820. *Drawings by Dr. J. H. H. H. H.*

This drawing and those of figures 6 and 10 are from specifications, sketches, and photographs, now in the files of the division of transportation, U. S. National Museum, taken in 1925 by Paul F. Garber from a wagon then the property of Amos Gingrich, Lancaster, Pennsylvania. This wagon is illustrated in John Omwake's *Conestoga six-horse belt teams, 1750-1850*, Cincinnati, 1930, pp. 57, 63, 87.

a: Bed and running gear, right side: 1, Bows for supporting cover. 2, Ridgepole, or stringer. 3, Top rail, with bow staples and side-board staples. 4, Side-boards, removable. 5, Feedbox in traveling position. 6, Rubbing plates to prevent wheels wearing wooden frame. 7, Side-board standards, forming framework of sides (on the inside, a few of these sometimes project

a few inches above the top rail to support the side-boards). 8, Securing rings for the ends of the spread chains, two of which span the bed to give extra support to the sides against inside pressures.

b: Tongue, or pole, top and side views. 1, Double-tree hasp, shown in proper position over the double-tree in the lower drawing; the hammer-headed double-tree pin goes through it, then through the double-tree and the tongue. 2, Wear plate on double-tree pin. 3, Feedbox staple; in use, the feedbox is unhocked from the rear, the long pin on the end of the box is passed through the hole for the double-tree pin, and the lug on the other end of the box is slipped through the staple. 4, Hitching rings for securing horses while leading. 5, End ring.

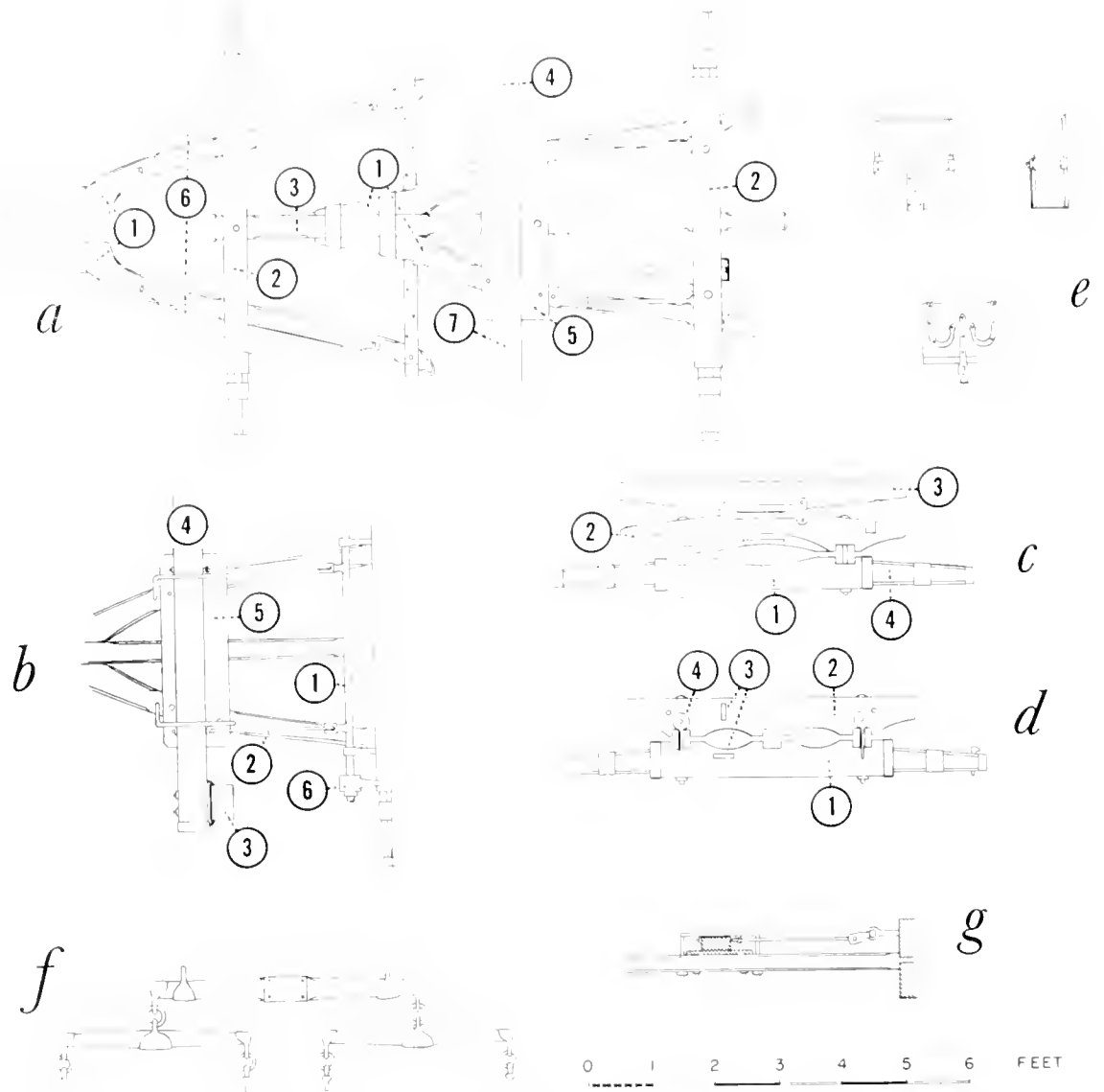


Figure 9. DETAILS OF THE FREIGHT-CARRYING WAGON, 1800-1820, OF FIGURE 8. (Drawing by Donald W. Holst.)

a: Running gear, top view: 1, Front and rear hounds. 2, Bolsters, with axletrees directly underneath. 3, Coupling pole. 4, Brake beam. 5, Brake-beam shelf, or support. 6, Segments forming the fifth wheel; these prevented the bed from toppling, or swaying excessively on turns. 7, Rear brace for front hounds, to keep tongue from dropping.

b: Brake mechanism, detail: 1, Brake rocker bar, with squared end for brake lever. 2, Rods connecting rocker bar to brake beam. 3, Rubber, or brakeshoe, made of wood, often faced with old leather. 4, Brake beam. 5, Brake-beam shelf, or support. 6, Brake lever, often 4 or 5 feet long.

c: Front axletree and bolsters, front view: 1, Axletree. 2, Bolster, showing wear plates. 3, Upper bolster, actually part of the wagon bed. 4, Axle, showing ironing.

d: Rear axletree and bolster, rear view: 1, Axletree, showing linchpin in position in right axle. 2, Bolster. 3, Hook and staple for holding bucket of tar used in lubricating axles. 4, Hound pins.

e: Toolbox, showing front, end, and top; it was secured to left side of wagon.

f: Doubletree, with singletrees attached.

g: Brake mechanism, side view.



Figure 10. DETAILS OF THE FREIGHT-CARRYING WAGON, 1800-1820, OF TYPE B. *Details of Details of the History*

a: Feedbox: 1, Top; 2, Side, showing pin and lug for securing to tongue; 3, Lid, showing bracket into which the chains hooked for traveling.

b: Front end panel: 1, Bottom end rail; 2, Middle end rail; 3, Top end rail; 4, Standard, or upright, forming end framing; 5, End boards; 6, Bow; 7, Corner plates.

c: Rear end gate: 1, Staples for end-gate standards; 2, End-gate hasps and hooks; 3, Pins to secure gate to upper side rails; 4, Crossbar to give extra support to end gate.

d: Rear wheel.

1, Cross section of wheel; 2, Boxes, of cast iron, wedged in hub to take wear of axle.

e: Front wheel: 1, Felly, or felloe; 2, Spoke; 3, Hub, or nave.

f: Floor of wagon, from under side view. Center beams, the center and rear ones being heavier, and protruding at the ends to hold the non-side beams visible in figure B. 1, 2, Bottom side rails; 3, Floor boards; 4, Position of rear bolts, which held us on running gear; 5, Front beams, showing bolt, knipin.

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 10

OLD ENGLISH PATENT MEDICINES IN AMERICA
*George B. Griffenhagen and
James Harvey Young*

ORIGINS OF ENGLISH PATENT MEDICINES	156
ENGLISH PATENT MEDICINES COME TO AMERICA	162
COMPLEX FORMULAS AND DISTINCTIVE PACKAGES	166
SOURCE OF SUPPLY SEVERED	168
PHILADELPHIA COLLEGE OF PHARMACY FORMULARY	174
ENGLISH PATENT MEDICINES GO WEST	176
THE PATENT MEDICINES IN THE 20TH CENTURY	179

OLD ENGLISH PATENT MEDICINES IN AMERICA

By George B. Griffenhagen and James Harvey Young

Bateman's Pectoral Drops, Godfrey's Cordial, Turlington's Balsam of Life, Hooper's Female Pills, and a half-dozen other similar nostrums originated in England, mostly during the first half of the 18th century. Advertised with extravagant claims, their use soon spread to the American Colonies.

To the busy settler, with little time and small means, these ready-made and comparatively inexpensive "remedies" appealed as a solution to problems of medical and pharmaceutical aid. Their popularity brought forth a host of American imitations and made an impression not soon forgotten or discarded.

THE AUTHORS: George B. Griffenhagen, formerly curator of medical sciences in the Smithsonian Institution's U.S. National Museum, is now Director of Communications for the American Pharmaceutical Association. James Harvey Young is professor of history at Emory University. Some of the material cited in the paper was found by him while he held a fellowship from the Fund for the Advancement of Education, in 1954-55, and grants-in-aid from the Social Science Research Council and Emory University, in 1956-57.

IN 1824 THERE ISSUED from the press in Philadelphia a 12-page pamphlet bearing the title, *Formulae for the preparation of eight patent medicines, adopted by the Philadelphia College of Pharmacy*. The College was the first professional pharmaceutical organization established in America, having been founded in 1821, and this small publication was its first venture of any general importance. Viewed from the perspective of the mid-20th century, it may seem strange if not shocking that the maiden effort of such a college should be publicizing formulas for nostrums. Adding to the novelty is the fact that all eight of these patent medicines, with which the Philadelphians concerned themselves half a century after American independence, were of English origin.

Hooper's Female Pills, Anderson's Scots Pills, Bateman's Pectoral Drops, Godfrey's Cordial, Dalby's Carminative, Turlington's Balsam of Life, Steer's Opododoc, British Oil—in this order do the names appear in the Philadelphia pamphlet—all were products of British therapeutic ingenuity. Across the Atlantic Ocean and on American soil these eight and other old English patent medicines, as of the year when the 12-page pamphlet was printed, had both a past and a future.

Origin of English Patent Medicines

When the Philadelphia pharmacists began their study, the eight English patent medicines were from

half a century to two centuries old.¹ The most ancient was Anderson's Scots Pills, a product of the 1630's, and the most recent was probably Dalby's Carminative, which appeared upon the scene in the 1780's. Some aspects of the origin and development of these and similar English proprietaries have been treated, but a more thorough search of the sources and a more integrated and interpretive recounting of the story would be a worthy undertaking. Here merely an introduction can be given to the cast of characters prior to their entrances upon the American stage.

The inventor of Anderson's Scots Pills was fittingly enough a Scot named Patrick Anderson, who claimed to be physician to King Charles I. In one of his books, published in 1635, Anderson extolled in Latin the merits of the Grana Angelica, a pill the formula for which he said he had learned in Venice. Before he died, Anderson imparted the secret to his daughter Katherine, and in 1686 she in turn conveyed the secret to an Edinburgh physician named Thomas Weir. The next year Weir persuaded James II to grant him letters patent for the pills. Whether he did this to protect himself against competition that already had begun, or whether the patenting gave a cue to those always ready to cut themselves in on a good thing, cannot be said for sure. The last years of the 17th century, at any rate, saw the commencement of a spirited rivalry among various makers of Anderson's Scots Pills that was long to continue. One of them was Mrs. Isabella English, an enterprising woman who sealed her pill boxes in black wax bearing a lion rampant, three mallets argent, and the bust of Dr. Anderson. Another was a man named Gray who sealed his boxes in red wax with his coat of arms and a motto strangely chosen for a medicine, "Remember you must die."

FORMULÆ

FOR THE

PREPARATION OF EIGHT

PATENT MEDICINES,

ADOPTED BY THE

PHILADELPHIA COLLEGE

OF

PHARMACY

MAY 4th, 1824.

SOLOMON W. CONRAD, PRINTER,

No. 32, Church Alley.

Figure 1. —THE PHILADELPHIA COLLEGE OF PHARMACY in 1824 set forth in this pamphlet formulas for eight old English patent medicines. (*Courtesy, Philadelphia College of Pharmacy and Science, Philadelphia, Pennsylvania*)

Competition already had begun when Godfrey's Cordial appeared in the record in a London newspaper advertisement during December 1721. John Fisher of Hertfordshire, "Physician and Chymist," claimed to have gotten the true formula from its originator, the late Dr. Thomas Godfrey of the same county. But there is an alternate explanation. Perhaps the Cordial had its origin in the apothecary shop established about 1660 by Ambroise Hencke-

¹ Unless otherwise indicated, the early English history of these patent medicines has been obtained from the following sources: "Proprietaries of other days," *Chemist and Druggist*, June 25, 1927, vol. 106, pp. 831-840; C. J. S. Thompson, *The mystery and art of the apothecary*, London, 1929; C. J. S. Thompson, *Quacks of old London*, London, 1928; and A. C. Wootton, *Chronicles of pharmacy*, London, 1910, 2 vols.

Elixir Salutis:

THE
CHOISE DRINK OF HEALTH,

O R,
Health-Bringing Drink.

BEING

A Famous Cordial Drink, found out
by the Providence of the Almighty, and Ex-
perienced a Most Excellent Preservative of
Man-kind,

A SECRET

Far beyond any Medicament yet known,
And is found so agreeable to Nature, That
it Effects all its Operations, as Nature would
Have it, and as a Vertual Expedient proposed by
her, for reducing all her Extrems unto an equal
Temper; the same being fitted unto all Ages, Sexes,
Complexions and Constitutions, and highly fortifying
Nature against any Noxious humour, invading or
offending the Noble Parts:

Never Published by any but by Me
ANTHONY DAFFY, Student in Physick.

LONDON,

Printed with Allowance for the Ambour by T. Malsbourn, 1673.

Figure 2.—ANTHONY DAFFY EXTOLLED THE VIRTUES OF HIS ELIXIR SALUTIS in this pamphlet, published in London in 1673. (Courtesy, British Museum.)

witz) Godfrey in Southampton Street, London.² According to a handbill issued during the late 17th century, Ambroise Godfrey prepared "Good Cordials as Royal English Drops."

With respect to his rivals, the 18th-century Hertfordshire vendor of the Cordial warned in the *Weekly Journal* (London), December 23, 1721: "I do advise all Persons, for their own Safety, not to meddle with the said Cordial prepared by illiterate and ignorant Persons, as Bakers, Malsters, [sic] and Goldsmiths,

² "How the patent medicine industry came into its own," *American Druggist*, October 1933, vol. 88, pp. 84-87, 232, 234, 236, 238.

that shall pretend to make it, it being beyond their reach: so that by their Covetousness and Pretensions, many Men, Women, and especially Infants, may fall as Victims, whose Slain may exceed Herod's Cruelty"

In 1726 King George I granted a patent for the making and selling of Dr. Bateman's Pectoral Drops. The patent was given not to a doctor, but to a business man named Benjamin Okell. In the words of the patent,³ Okell is lauded for having "found out and brought to Perfection, a new Chymicall Preparacion and Medicine . . . , working chiefly by Moderate Sweat and Urine, exceeding all other Medicines yet found out for the Rheumatism, which is highly useful under the Afflictions of the Stone, Gravel, Pains, Agues, and Hysterias . . ." What the chemicals constituting his remedy were, the patentee did not vouchsafe to reveal.

The practice of patenting had begun in royal prerogative. Long accustomed to granting monopoly privileges for the development of new industries, the discovery of new lands, and the enrichment of court favorites, various monarchs in 17th-century Europe had given letters patent to proprietors of medical remedies which had gained popular acclaim. In France and the German States, this practice continued well through the 18th century. In England, where representative government had progressed at the expense of the personal prerogative of the sovereign, Parliament passed a law in 1624 aimed at curbing arbitrary actions like those of James I and Charles I. The statute declared all monopolies void except those extended to the first inventor of a

new process of manufacture. To such pioneers the king could grant his letters patent bestowing monopoly privileges for a period of 14 years. That the machinery set up by this law did not completely curb the independence of English sovereigns in the medical realm is indicated by the favor extended Dr. Weir, who successfully sought from James II a privileged position for Anderson's Scots Pills. This kingly grant is not included in the regular list, and the Glorious Revolution of 1688 brought an end to such an exercise of

³ Benjamin Okell, "Pectoral drops for rheumatism, gravel, etc.," British patent 483, March 31, 1726.

royal power without consent of Parliament. A list of patents in the medical field later published by the Commissioners of Patents⁴ includes only six issued during the 17th century, four for baths and devices, one for an improved method of preparing alum, and one for making epsom salts. The first patent for a compound medicine was granted in 1711, and only two other proprietors preceded Benjamin Okell in seeking this particular legal form of protection and promotion.

As early as 1721, Bateman's Pectoral Drops were being regularly advertised in the *London Mercury*. The advertisements announced: "Dr. Bateman's Pectoral Drops published at the Request of several Persons of Distinction from both Universities . . ." The Drops, priced at "1 s. a Bottle," were "Sold Wholesale and Retail at the Printing-house and Picture Warehouse in Bow Churchward," and likewise "in most Cities and celebrated Towns in Great Britain," "Each Bottle Seal'd with the Boar's Head." So stated the advertisement, which itself contained a crude cut of this Boar's Head seal.⁵ Elsewhere in this issue of the *Mercury*, we learn that John Cluer, printer, was the proprietor of the Bow Churchward Warehouse. This same John Cluer, along with William Dicey and Robert Raikes, were named in the 1726 patent as "the Persons concerned with the said Inventor," Benjamin Okell, who, with him, should "enjoy the sole Benefit of the said Medicine." It was this partnership which was to find the field of nostrum promotion especially congenial and which was to play an important transatlantic role. Soon after securing their patent, the proprietors undertook to inform their countrymen about the remedy by issuing *A short treatise of the virtues of Dr. Bateman's Pectoral Drops*.⁶

It was the 18th century, and the essay was in fashion. The proprietors prepared a didactic introduction to their treatise, phrased in long and flowery sentences, in which modesty was not the governing tone. The arguments ran like this: that the "Universal Good of Mankind" should be the aim of "every private member"; that nothing is so conducive to this general wel-

fare as "HEALTH"; that no hazards to health are more direful than diseases such as "the Gout; the Rheumatism; the Stone; the Jaundice," etc., etc.; that countless men and women have succumbed to such afflictions either because they received no treatment or suffered wrong treatment at "the Hands of the Learned"; that no medicine is so sure a cure as that inexpensive remedy discovered as a result of great "Piety, Learning and Industry" by one "inspir'd with the Love of his Country, and the Good of Mankind," to wit, "DR. BATEMAN'S Pectoral Drops."

Then followed seven chapters treating the multitude of illnesses for which the Drops were a specific. Finally, the pamphlet cited "some few, out of the many thousands of Certificates of Cures effected by these Drops. . . ." Even so early was the testimonial deemed a powerful persuader.

No more could Okell, Cluer, Dicey, and Raikes escape competition than could the proprietors of other successful nostrums. In 1755 they went to court and won a suit for the infringement of their patent, but the damages amounted to only a shilling. Even after the patent expired, the tide of publicity flowed on.⁷

Competition was also lively in the 1740's among some half a dozen proprietors marketing a form of crude petroleum under the name of British Oil. Early in the decade Michael and Thomas Betton were granted a patent for "An Oyl extracted from a Flinty Rock for the Cure of Rheumatick and Scorbutick and other Cases." The source of the oil, according to their specifications, was rock lying just above the coal in mines, and this rock was pulverized and heated in a furnace to extract all the precious healing oil.⁸ This Betton patent aroused one of their rivals, Edmund Darby & Co., of Coalbrook-Dale in Shropshire. Darby asserted that it was presumptuous of the Bettons to call their British oyl a new invention.⁹

⁴ A broadside, issued in London, ca. 1750, advertising "Dr. Bateman's Drops," is preserved in the Warshaw Collection of Business Americana, New York. Later reprints of this same broadside are preserved in the private collection of Samuel Aker, Albany, New York, and in the Smithsonian Institution.

⁵ Michael and Thomas Betton, "Oil for the cure of rheumatic and scorbutic affections," British patent 587, August 13, 1742.

⁶ Edmund Darby & Co., *Dr. Bateman's Pectoral Drops, being a short treatise of the virtues thereof, as also a receipt for the Oyl, prepared by Edward Darby & Co. at Coalbrook-Dale, Shropshire*, ca. 1735. An 8-page pamphlet preserved in the Library of the College of Physicians, Philadelphia, Pennsylvania.

⁴ British Patent Office, *Patents for inventions: abridgements of specifications relating to medicine, surgery, and dentistry, 1620-1800*, London, 1872.

⁵ *London Mercury*, London, August 19-26, 1721.

⁶ *A short treatise of the virtues of Dr. Bateman's Pectoral Drops*, New York, 1731. A 36-page pamphlet preserved in the Library of the New York Academy of Medicine. This is an American reprint of an English original, date unknown.

For over a century Darby and his predecessors had been marketing this self-same product, and it had proved to be “the one and only unrivall’d and most efficacious Remedy ever yet discovered, against the whole force of Diseases and Accidents that await Mankind. . . .” For the Bettons to appropriate the process and patent it—and even to claim in their advertising cures which really had been wrought by the Darby product—was scandalous. Worse than that, said Darby, it was illegal, for in 1693 William III had granted a patent to “Martin Ecle and two others at his Nomination for making the same Sort of Oyl from the same Sort of Materials.”⁹ Evidence to substantiate his belief in the Betton perfidy was presented by Darby to George II, who had the matter duly investigated.¹⁰ Being persuaded that Darby was right, the king and his councillors, in 1745, vacated the Betton patent. This victory seems not to have boomed the Darby interests, and this defeat seems not to have ruined the Bettons. During the succeeding century, the Betton patent was published and republished in advertising, just as if it had never fallen afoul the law. From their battles with the Oil from Coalbrook-Dale and other British Oils marketed by other proprietors, the Bettons emerged triumphant. In the years to come, patent or no, the Bettons British Oil was to dominate the field.

The year after the Bettons had secured their patent, another was granted to John Hooper of Reading for the manufacture of “Female Pills” bearing his name.¹¹ Hooper was an apothecary, a man-midwife, and a shrewd fellow. This was the period in which the British Government was increasing its efforts to require the patentee to furnish precise specifications with his application.¹² When Hooper was called upon to tell what was in his pills and how they were made, he replied by asserting that they were composed “Of the best purging stomatick and anti-hysterick ingredients,” which were formed into pills the size of a small pea. This satisfied the royal agents and Hooper went on about his business. In an advertisement of the same year, he was able to cite as a witness to his patent the name of the Archbishop of Canterbury.¹³

Much less taciturn than Hooper about the composition of his nostrum was Robert Turlington, who secured a patent in 1744 for “A specifick balsam, called

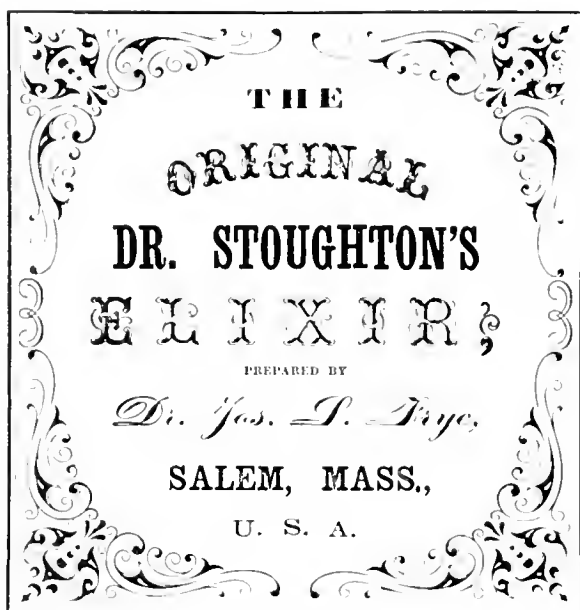


Figure 3. LABEL FOR STOUGHTON'S ELIXIR as manufactured by Dr. Jos. Frye of Salem, Massachusetts. (Courtesy, Essex Institute, Salem, Massachusetts.)

the balsam of life.”¹⁴ The Balsam contained no less than 27 ingredients, and in his patent specifications Turlington asserted that it would cure kidney and bladder stones, cholic, and inward weakness. He shortly issued a 46-page pamphlet in which he greatly expanded the list.¹⁵ In this appeal to 18th-century sensibilities, Turlington asserted that the “Author of Nature” has provided “a Remedy for every Malady.” To find them, “Men of Learning and Genius” have “ransack’d” the “Animal, Mineral and Vegetable World.” His own search had led Turlington to the Balsam, “a perfect Friend to Nature, which it strengthens and corroborates when weak and declining, vivifies and enlivens the Spirits, mixes with the Juices and Fluids of the Body and gently infuses its kindly Influence into those Parts that are most in Disorder.”

Testimonials from those who had felt the kindly influence took up most of the space in Turlington’s pamphlet. In these grateful acknowledgments to the potency of the patent medicine, the list of illnesses cured stretched far beyond the handful named in the patent specifications. Just as for Bateman’s Pectoral Drops

⁹ *London Gazette*, London, March 1, 1745.

¹⁰ John Hooper, “Pills,” British patent 592, July 21, 1743.

¹¹ E. Burke Inlow, *The patent grant*, Baltimore, 1950, p. 33.

¹² *Daily Advertiser*, London, September 23, 1743.

¹⁴ Robert Turlington, “A Specifick balsam, called the balsam of life,” British patent 596, January 18, 1744.

¹⁵ Robert Turlington, *Turlington’s Balsam of Life*, ca. 1747. A 46-page pamphlet preserved in the Folger Shakespeare Library, Washington, D. C.

and the Darby brand of British Oil, workers of many occupations solemnly swore that they had received benefit. Most of them were humble people—a porter, a carpenter, the wife of a gardener, a blanket-weaver, a gunner's mate, a butcher, a hostler, a bodice-maker. Some bore a status of greater distinction: there were a "Mathematical Instrument-Maker" and the doorkeeper of the East India Company. All were jubilant at their restored good health.

The Balsam's well-nigh sovereign power could not protect it from one ailment of the times, competition. Various preparations of similar composition, like Friar's Balsam, already were on the market, but before long even the Turlington name was trespassed upon, and the inventor's niece was forced to advertise that she alone had the true formula and that any person who took a dose of the spurious imitations being offered did so at great hazard to his life.

A quarter of a century after the patenting of the Balsam, there appeared for sale to British ailing a remedy called Dr. Steer's Celebrated Opodeldoc. Dr. Steer is a shadowy rider of a vigorous steed, for although the doctor has left but a faint personal impact upon the historical record, Opodeldoc has pranced through medical history since the time of Paracelsus. This 16th-century continental chemist-physician, who introduced many mineral remedies into the materia medica, had coined the word "opodeldoc" to apply to various medical plasters. In the two ensuing centuries the meaning had changed, and the *Pharmacopœia Edinburgensis* of 1722 employed the term to designate soap liniment. It is presumed that Dr. Steer appropriated the Edinburgh formula, added ammonia, and marketed his proprietary version. In 1780, a London paper carried an advertisement listing the difficulties for which the Opodeldoc was a "speedy and certain cure." These included bruises, sprains, burns, cuts, chilblains, and headaches. Furthermore, the remedy had been "found of infinite Use in hot Climates for the Bite of venomous Insects."¹⁶ Dr. Steer seems not to have secured a patent for his slightly modified version of an official preparation. He died in 1781, but Opodeldoc, indeed Steer's Opodeldoc, went marching on.¹⁷

¹⁶ *Daily Advertiser*, London, February 18, 1780.

¹⁷ Broadside, ca. 1810-1822, advertising "Steer's Chemical Opodeldoc, for bruises, sprains, rheumatism, etc., etc.," are preserved in the American Antiquarian Society, Worcester, Massachusetts; the Library of the New York Academy of Medicine; and the Warshaw Collection of Business Americana, New York.

About the same time that Dr. Steer began advertising, newspaper promotion was launched in behalf of another remedy, called Dalby's Carminative. The inventor, J. Dalby, was a London apothecary, and his unpatented concoction was designed to cure "Disorders of the Bowels." One early advertisement added details: "This Medicine, which is founded on just Medical Principles, has been long established as a most safe and effectual Remedy, generally affording immediate Relief in the Wind, Cholocks [sic], Convulsions, Purgings, and all those fatal Disorders in the Bowels of Infants, which carry off so great a number under the age of 2 years. It is also equally efficacious in gouty Pains in the Intestines, in Fluxes, and in the cholicky Complaints of grown Persons, so usual at this Season of the Year." Dalby, like Steer, failed long to survive the appearance of his medicine on the market.

Such were the origins of the eight remedies which the Philadelphia pharmacists were to take account of in 1824. Besides these eight, two other patent medicines, both elixirs, were destined for roles of such special interest that a brief look at their English background is warranted.

One of them, Dalby's Elixir, was the invention of a clergyman, Rev. Thomas Dalby soon after 1650. Dalby had his troubles during that troubled century, losing a pastorate because he offended a powerful Countess. When the rector first sought to minister unto men's bodies as well as to their souls is not known. According to a pamphlet issued in 1673, after the Rev. Dalby had passed from the scene, the formula had been "found out by the Providence of the Almighty." By this time a London kinsman of the inventor, named Anthony Dalby, was vending the remedy. The full name of the medicine, according to the pamphlet's title, was "Elixir Salutis: The Choice Drink of Health, or Health-Bringing Drink," and among the ailments for which it was effective were gout, the stone, colic, "püssick," scurvy, dropsy, rickets, consumption, and "languishing and melancholly."

The Elixir Salutis proved immensely popular. It was too much to expect that Anthony should hold the field uncontested; in the 1673 pamphlet one false fabricator was called by name, and in 1683 Anthony advertised to warn against "diverse Persons" who were not only counterfeiting the medicine but spreading the malicious rumor that Anthony was dead. Early in

¹⁸ *Daily Advertiser*, London, January 3, 1781.

the new century, Catherine, the daughter of the original Rev. Dally, insisted that she as well as her cousin Anthony had received the valuable formula. But it was Anthony's line that was to prove the more persistent. In 1743, one Susannah Dally advertised the "Original and Famous Elixir," asserting that she had a brother Anthony who also knew the secret.¹⁹ This Anthony died in 1750 and willed the formula to his niece. But there were others outside the family who long had been making and selling the medicine. For example, the Bow Churchyard Warehouse advertised Dally's Elixir in the *London Mercury* during 1721. Without hiding the fact that others were also compounding this "safe and pleasant Cordial . . . well-known throughout England, where it has been in great Use these 50 Years," the advertisement concluded: "Those who make trval of That sold at this [Bow Churchyard] Warehouse will never buy anywhere else."²⁰

Although once lauded by a physician to King Charles II, Dally's Elixir was never patented. The Elixir invented by Richard Stoughton was, in 1712, the second compound medicine to be granted a patent in England.²¹ Stoughton was an apothecary who had a shop at the Sign of the Unicorn in Southwark, Surrey. It was evidently competition, the constant bane of the medicine proprietor's life, that drove him to seek governmental protection. In his specifications he asserted that he had been making his medical mixture for over twenty years. Stoughton was less precise about his formula; indeed, he gave none, but was generous in indicating the remedy's name: "Stoughton's Elixir Magnum Stomachii, or the Great Cordial Elixir, otherwise called the Stomatick Tincture or Bitter Drops." In a handbill, the apothecary did tip his hand to the extent of asserting that his Elixir contained 22 ingredients, but added that nobody but himself knew what they were. The dosage was generous, 50 to 60 drops "in a glass of Spring water, Beer, Ale, Mum, Canary, White wine, with or without sugar, and a dram of brandy as often as you please." This, it was said, would cure any stomach ailment whatever.²²

¹⁹ *Ibid.*, September 7, 1743.

²⁰ *London Mercury*, London, August 19–26, 1721.

²¹ Richard Stoughton, "Restorative cordial and medicine," British patent 390, 1712.

²² From a broadside, *n.* 1750, advertising "Dr. Stoughton's Elixir Magnum Stomachum," preserved in the American Antiquarian Society, Worcester, Mass.

The inventor died in 1726, and his passing precipitated a perfect fury of competitive advertising. As in the case of Dally's, there was a family feud. A son of Stoughton and the widow of another son argued vituperously in print, each claiming sole possession of Richard's complicated secret, and each terming the other a scoundrel. The daughter-in-law accused the son of financial chicanery, and the son condemned the daughter-in-law for having run through two husbands and for desperately wanting a third. In the midst of this running battle, a third party entered the lists as maker of the Elixir. She was no Stoughton—though a widow—and her quaint claim for the public's consideration lay in this, that her late husband had infringed Stoughton's patent until restrained by the Lord Chancellor.

These ten medicines—Stoughton's and Dally's Elixirs and the eight which the Philadelphia pharmacists were later to select—were by no means the only packaged remedies available to the 18th-century Englishman who resorted to self-dosage for his ills. Between 1711, when the first patent was granted for a compound medicine, and 1776, some 75 items were patented in the medical field.²³ And, along with Godfrey's Cordial and Dally's Elixir, there were scores of other remedies for which no patents had been given. A list of nostrums published in *The Gentleman's Magazine* in 1748 totaled 202, and it was admittedly incomplete.²⁴ The proprietor with a patent might do his utmost to keep this badge of governmental sanction before the public, but the distinction was not great enough in such a crowded field to make things clear. The casual buyer could not keep track of which electuary had been granted a patent and which lozenge had not. They were all bottles and boxes upon the shelf. In use they served the same purpose. One term arose in common speech to apply to both, and it was "patent medicine."

English Patent Medicines Come to America

When the first English packaged medicine, patented or unpatented, came to the New World, cannot be told. Some 17th-century prospective colonist, setting forth to face the hazards of life in Jamestown or Baltimore or Boston, must have packed a box of Anderson's Scots Pills or a bottle of Dally's Elixir

²³ British Patent Office, *op. cit.* (see footnote 4).

²⁴ Poplicola, "Pharmacopœia empirica or the list of nostrums and empirics," *The Gentleman's Magazine*, 1748, vol. 18, pp. 346–350.



Figure 4. PATRICK ANDERSON, M. D., from a box of Anderson's Scots Pills. From Wootton's *Chronicles of pharmacy*, London, 1910. (Smithsonian photo 44286 C.)

to bring along, but no record to substantiate such an incident has been encountered. It would seem that the use of English packaged remedies in America was most infrequent before 1700. Samuel Lee, answering questions posed from England in 1690 about the status of medicine and pharmacy in Massachusetts, mentions no patent medicines.²⁵ Neither does the 1698 account book of the Salem apothecary, Bartholomew Brown.²⁶

In the *Boston News-Letter* for October 4, 1708, Nicholas Boone, at the Sign of the Bible, near the corner of School-House-Lane, advertised for sale: "DAFFY'S Elixir Salutis, very good, at four shillings and sixpence *per* half pint Bottle." This may well be the first printed reference in America to an English patent medicine, and it certainly is the first newspaper advertisement for a nostrum. Preceding the *News-Letter* in colonial America, there had been only one paper, the *Publick Occurrences Both Foreign*

and Domestic. This journal had lasted but a single issue. Then its printer had returned to England, where he took up the career of a patent medicine promoter, vending "the only Angelical Pills against all Vapours, Hysterick and Melancholly Fits." The *News-Letter* had begun with the issue of April 27, 1704, about 4 years before Boone's advertisement for Daffy's remedy made its appearance, but during that time, only one advertisement for anything at all in the medical field had appeared, and that was for a home-remedy book, *The English physician*, by Nicholas Culpeper, Doctor of Physick.²⁷ This volume was also for sale at Boone's shop.

Patent-medicine advertising in the *News-Letter* prior to 1750 was infrequent. Apothecary Zabdiel Boylston, who a decade later was to earn a role of esteem in medical history by introducing the inoculation for smallpox, announced in 1711 that he would sell "the true Lockyers Pills."²⁸ This was an unpatented remedy first concocted half a century earlier by a "licensed physitian" in London. The next year Boylston repeated this appeal,²⁹ and in the same advertisement listed other wares of the same type. He had two varieties, Golden and Plain, of the Spirit of Scurvy-Grass; he had "The Bitter Stomach Drops," worm potions for children; and a wonderful multipurpose nostrum, "the Royal Honey Water, an Excellent Perfume, good against Deafness, and to Make Hair grow. . . ." The antecedents of this regal liquid are unknown. Boylston also announced for sale "The Best [Daffy's] Elixir Salutis in Bottles, or by the Ounce." This is a provocative listing. It may mean merely that the apothecary would break a bottle to sell a dose of the Elixir, which was often the custom. But it also may suggest that Boylston was making the Elixir himself, or was having it prepared by a journeyman. This latter interpretation would place Boylston well at the head of a long parade of American imitators of the old English patent medicines.

Other such shipments of the packaged English remedies may have come to New England on the latest ships from London during the next several decades, but they got scant play in the advertising columns of the small 4-page *Boston News-Letter*. Another reference to "Doctor Anthony Daffey's Orig-

²⁵ George L. Kittredge, "Letters to Samuel Lee and Samuel Sewall relating to New England and the Indians," *Colonial Society of Massachusetts, Transactions*, 1913, vol. 14, pp. 142-186.

²⁶ Bartholomew Brown, Apothecary day book, Salem [1698], manuscript original preserved in the Library of the Essex Institute, Salem, Massachusetts.

²⁷ Frank L. Mort, *Antiquarian*, New York, 1931, pp. 9-10.

²⁸ *Boston News-Letter*, Boston, February 3, 1708.

²⁹ *Ibid.*, March 12, 1711.

Ibid., March 23, 1712.

inal Elixer Salutis" occurs in 1720.³¹ Ten years later, Stoughton's Drops were announced for sale "by Public Vendue," along with feather beds, looking glasses, and leather breeches.³² Nearly a decade more was to pass before Bateman's Pectoral Drops showed up in the midst of another general list, including cheese, and shoes, and stays.³³ Not until 1748 did an advertisement appear in which several of the old English nostrums rubbed shoulders with each other.³⁴ Then Silvester Gardiner, at the Sign of the Unicorn and Mortar, asserted that "by appointment of the Patentee" he was enabled to sell "Genuine British Ovl, *Bateman's Pectoral Drops*, and *Hooper's Female Pills*, and the *True Lockyer's Pills*."

Although nearly a century old, Anderson's Scots Pills were not cited for sale in the pages of the *Boston News-Letter* until August 23, 1750, two months after the much more recent Turlington's Balsam of Life first put in its appearance.³⁵ During the same year, the British confusion over British Oil was reflected in America. Boden's and Darby's variety preceded the Betton brand into the *News-Letter* pages by a fortnight.³⁶ It was the latter, however, which was to win the day in Boston, for almost all subsequent advertising specified the Betton Oil. Godfrey's Cordial was first mentioned in 1761.³⁷ Thus, of the ten old English patent medicines which are the focus of the present study, eight had been advertised in the *Boston News-Letter*. The other two, Steer's Opodeldoc and Dalby's Carminative, did not reach the market before this colonial journal fell prey to the heightening tensions of early 1776.

By the 1750's, the names of several old English nostrums were appearing fairly frequently in the advertising of colonial apothecaries, not only in Boston but in other colonial towns. In Williamsburg, for example, a steady increase occurs in the number of references and the length of the lists of the English patent medicines advertised in the *Virginia Gazette* from their first mention into the early 1760's.³⁸ This journal—which later had competing issues by different editors—was launched in 1736, and the next

year George Gilmer advised customers that, in addition to "all manner of Chymical and Galenical Medicines," he could furnish, at his old shop near the Governor's, "Bateman's Drops, Squires Elixir, Anderson's Pills."³⁹ The other remedies appeared in due time, Stoughton's and Daffy's Elixirs in 1745, Turlington's Balsam in 1746, Godfrey's Cordial in 1751, Hooper's Pills in 1752, and Betton's British Oil in 1770.

A spot check of newspapers in Philadelphia and New York reveals a pattern quite similar. Residents of the middle colonies, like those to the north and the south, could buy the basic English brands, and it was during the 1750's that the notices of freshly-arrived supplies ceased to be rare in advertising columns and became a frequent occurrence. Thomas Preston, for example, announced to residents of Philadelphia in 1768 that he had just received a supply of Anderson's, Hooper's, Bateman's, Betton's, Dally's, Stoughton's, Turlington's, and Godfrey's remedies.⁴⁰ Not only were these medicines for sale at apothecary shops, but they were sold by postmasters, goldsmiths, grocers, hair dressers, tailors, printers, booksellers, cork cutters, the post-rider between Philadelphia and Williamsburg, and by many colonial American physicians.

It is a matter for comment that American newspaper advertising of the English packaged medicines was singularly drab. In the mother country, the proprietors or their heirs were faced with vigorous competition. It behooved them to sharpen up their adjectives and reach for their vitriol. In America the apothecary or merchant had no proprietary interest in any of the different brands of the imported medicines which were sold. Moreover, there was probably no great surplus of supply over demand in America as in Britain, so the task of selling the stock on hand was less difficult and required less vigorous promotion. Also, advertising space in the few American weeklies was more at a premium than in the more frequent and numerous English journals. With rare exceptions, therefore, the old English patent medicines were merely mentioned by name in American advertising. Seldom did one receive the individual attention accorded by Samuel Emlen to Godfrey's Cordial in Benjamin Franklin's *Pennsylvania Gazette* for June 26, 1732. The ad ran like this:

"Dr. Godfrey's General Cordial. So universally

³¹ *Virginia Gazette*, Williamsburg, May 27, 1737.

³² *Pennsylvania Gazette*, Philadelphia, December 1, 1768.

³³ *Ibid.*, November 14, 1720.

³⁴ *Ibid.*, March 12, 1730.

³⁵ *Ibid.*, January 4, 1739.

³⁶ *Ibid.*, November 14, 1748.

³⁷ *Ibid.*, June 7, 1750.

³⁸ *Ibid.*, May 24, 1750.

³⁹ *Ibid.*, December 31, 1761.

⁴⁰ Lester J. Cappon and Stella E. Duff, *Virginia Gazette index, 1736-1780*, Williamsburg, 1950, 2 vols.

A
Short TREATISE
 OF THE
VIRTUES
 OF
Dr. BATEMAN'S
PECTORAL DROPS:

The Nature of the Distemperr They
 Cure, and the Manner of Their Operation.

Publish'd by the KING's Letter Patents under
 the Great Seal of Great Britain.



The Seal of each Bottle.

To be Sold only by James Wallace, in New-York.

Reprinted by J. Peter Zenger, in New-York,

Figure 5.—PAMPHLET, DATED 1731, ON BEHALF OF BATEMAN'S PECTORAL DROPS. It was published by John Peter Zenger in New York. Original preserved in the New York Academy of Medicine Library. (Smithsonian photo 44280 D.)

approved of for the Cholick, and all Manners of Pains in the Bowels, Fluxes, Fevers, Small-Pox, Measles, Rheumatism, Coughs, Colds, and Restlessness in Men, Women, and Children; and particularly for several Ailments incident to Child-bearing Women, and Relief of young Children in breeding their Teeth."

Emlen's venturesomeness may have lain in the fact that he was not only a retailer, but also an agent for

the British manufacturer, for he stated the names of those who sold Godfrey's Cordial in nearby towns. Even at that, this appeal, consisting merely of a list of illnesses, lacked the cleverness of contemporary English nostrum advertising. In the whole span of the *Boston News-Letter*, beginning in 1704, it was not until 1765 that a bookstore pulled out the stops with half a column of lively prose in behalf of Dr. Hill's four unpatented nostrums.¹¹ It seems a safe assumption that not only the medicines but the verbiage were imported from London, where Dr. Hill had been at work endeavoring to restore a Greek secret which "converts a Glass of Water into the Nature and Quality of Asses Milk, with the Balsamick Addition. . . ."

The infrequency of extended fanciful promotion in behalf of the old English nostrums in American newspaper advertising may have been compensated for to some degree in broadside and pamphlet. A critic of the medical scene in New York in the early 1750's asserted that physicians used patent medicines which they learned about from "London quack bills." This doctor complained, these were often their only reading matter.¹² Such a judgment may be too severe. Certainly it is difficult to validate today. Such pamphlets and broadsides do appear in American archival collections. The Historical Society of Pennsylvania contains a 2-page Furlington broadside,¹³ while the Folger Shakespeare Library in Washington has an earlier 3-page Furlington pamphlet with testimonials reaching out toward America.¹⁴ One such certificate came from "a sailor before the mast, on board the ship Britannia in the New York trade," and another cited a woman living in Philadelphia who gave thanks for the cure of her dropsy.

A broadside in the Warshaw Collection touting Bateman's Drops noted that "extraordinary demands

¹¹ *Boston News-Letter*, Boston, November 23, 1765.
¹² James J. Walsh, *History of the Medical Profession in New York City*, New York, 1907.
¹³ Robert Furlington, "Furlington's Balsam," 1765, 2 pages. A later reprint of this same circular is preserved in the Warshaw Collection of Business Americana.
¹⁴ *Medical History of the Folger Shakespeare Library*, 1930, p. 107.

have been made for Maryland, New-York, Jamaica, etc. where their virtues have been truly experienced with the greatest satisfaction."⁴⁵ That such promotional items are extremely rare does not mean they were not abundant in the mid-18th century, for this type of printed matter, then as now, was likely to be looked at and thrown away. A certain amount of nostrum literature was undoubtedly imported from Britain. For example, in 1753 apothecary James Carter of Williamsburg ordered from England "3 Quire Stoughton's Directions" along with "½ Groce Stoughton Vials."⁴⁶ These broadsides or circulars served a twofold purpose. Not only did they promote the medicine, but they actually served as the labels for the bottles. Early packages of these patent medicines which have been discovered indicate that paper labels were seldom applied to the glass bottles; instead, the bottle was tightly wrapped and sealed in one of these broadsides.

American imprints seeking to promote the English patent medicines were certainly rare. The most significant example may be found in the Library of the New York Academy of Medicine.⁴⁷ In 1731 James Wallace, a New York merchant, became American agent for the sale of Dr. Bateman's Pectoral Drops. To help him with his new venture, Wallace took a copy of the London promotional pamphlet to a New York printer to be reproduced. The printer was John Peter Zenger, not yet an editor and three years away from the events which were to link his name inextricably with the concept of the freedom of the press. This 1731 pamphlet may well have been the earliest work on any medical theme to be printed in New York.⁴⁸

Now and then a physician might frown on his fellows for reading such literature and prescribing such remedies, but he was in a minority. Colonial doctors, by and large, had no qualms about employing the packaged medicines. It was a doctor who first advertised Anderson's Pills and Bateman's Drops in Williamsburg;⁴⁹ it was another, migrating from England

to the Virginia frontier, who founded a town and dosed those who came to dwell therein with Bateman's Drops, Turlington's Balsam, and other patent medicines.⁵⁰

Complex Formulas and Distinctive Packages

Indeed, the status of medical knowledge, medical need, and medical ethics in the 18th century permitted patent medicines to fit quite comfortably into the environment. As to what actually caused diseases, man knew little more than had the ancient Greeks. There were many theories, however, and the speculations of the learned often sound as quaint in retrospect as do the cocky assertions of the quack bills. Pamphlet warfare among physicians about their conflicting theories achieved an acrimony not surpassed by the competing advertisers of Stoughton's Elixir. The aristocratic practitioners of England, the London College of Physicians, refused to expand their ranks even at a time when there were in the city more than 1,500 serious cases of illness a day to every member of the College. The masses had to look elsewhere, and turned to apothecaries, surgeons, quacks, and self-treatment.⁵¹ The lines were drawn even less sharply in colonial America, and there was no group to resemble the London College in prestige and authority. Medical laissez-faire prevailed. "Practitioners are laureated gratis with a title leather of Doctor," wrote a New Englander in 1690. "Potecaries, surgeons & midwives are dignified acc[ording] to successe."⁵² Such an atmosphere gave free rein to self-dosage, either with an herbal mixture found in the pages of a home-remedy book or with Daffy's Elixir.

In the 18th century, drugs were still prescribed that dated back to the dawn of medicine. There were Theriac or Mithridatum, Hiera Picra (or Holy Bitters), and Terra Sigillata. Newer botanicals from the Orient and the New World, as well as the "chymicals" reputedly introduced by Paracelsus, found their way into these ancient formulas. Since the precise action of individual drugs in relation to given ailments was but hazily known, there was a tendency to blanket assorted possibilities by mixing numerous ingredients into the same formula. The formularies of the Mid-

⁴⁵ "Dr. Bateman's Drops" (see footnote 7).

⁴⁶ James Carter, Apothecary account book, Williamsburg 1752-1773. Manuscript original preserved at Colonial Williamsburg, Virginia.

⁴⁷ *A brief treatise of the virtues of Dr. Bateman's Pectoral Drops* (see footnote 6).

⁴⁸ Gertrude E. Annan, "Printing and medicine," *Bulletin of the Medical Library Association*, March 1940, vol. 28, p. 155.

⁴⁹ Wynnham B. Blanton, *Medicine in Virginia in the eighteenth century*, Richmond, Virginia, 1934, pp. 33-34.

⁵⁰ Maurice Bear Gordon, *Asclepius comes to the colonies*, Ventnor, New Jersey, 1949, p. 39.

⁵¹ Fielding H. Garrison, *An introduction to the history of medicine*, Philadelphia, 1924, pp. 405-408; and Richard H. Shryock, *The development of modern medicine*, New York, 1947, pp. 51-54.

⁵² Kittredge, *op. cit.* (footnote 25).

dle Ages encouraged this so-called "polypharmacy." For example the *Antidotarium Nicolai*, written about A. D. 1100 at Salerno, described 38 ingredients in Confectio Adrianum, 35 ingredients in Confectio Atanasia, and 48 ingredients in Confectio Isdra. Theriac or Mithridatum grew in complexity until by the 16th century it had some 60 different ingredients.

It was in this tradition of complex mixtures that most of the patent medicines may be placed. Richard Stoughton claimed 22 ingredients for his Elixir, and Robert Turlington, in his patent specification, named 27. Although other proprietors had shorter lists or were silent on the number of ingredients, a major part of their secrecy really lay in having complicated formulas. Even though rivals might detect the major active ingredients, the original proprietor could claim that only he knew all the elements in their proper proportions and the secret of their blending.

Not only in complexity did the patent medicines resemble regular pharmaceutical compounds of the 18th century. In the nature of their composition they were blood brothers of preparations in the various pharmacopoeias and formularies. Indeed, there was much borrowing in both directions. An official formula of one year might blossom out the next in a fancy bottle bearing a proprietor's name. At the same time, the essential recipe of a patent medicine, deprived of its original cognomen and given a Latin name indicative of its composition or therapeutic nature, might suddenly appear in one of the official volumes.

For example, the formula for Daffy's Elixir was adopted by the *Pharmacopoeia Londinensis* in 1721 under the title of "Elixir Salutis" and later by the *Pharmacopoeia Edinburgensis* as "Tinctura sennae composita" (Compound Senna Tincture). Similarly the essential formula for Stoughton's Elixir was adopted by the *Pharmacopoeia Edinburgensis* as early as 1762 under the name of "Elixir Stomachium," and later as "Compound Tincture of Gentian" (as in the *Pharmacopoeia of the Massachusetts Medical Society* of 1808). Only two years after Turlington obtained his "Balsam of Life" patent, the *Pharmacopoeia Londinensis* introduced a recipe under the title of "Balsamum Traumaticum" which eventually became Compound Tincture of Benzoin, with the synonym Turlington's Balsam. On the other hand, none of these early English patent medicines, including Stoughton's Elixir and Turlington's Balsam, offered anything new, except possibly new combinations or new proportions of ingredients already widely employed in medicine. Formulas similar in



Figure 6. BOTTLES OF BATEMAN'S PECTORAL DROPS, 19th century (left) and early 20th century (right), from the Samuel Aker, David and George Kass collection, Albany, New York. (Smithsonian photo 41287-11)

composition to those patented or marketed as "new inventions" can in every case be found in such 17th-century pharmacopoeias as William Salmon's *Pharmacopoeia Londinensis*.

Whatever similarities existed between the canons of regular pharmacy and the composition of patent medicines, there was a decided difference in the methods of marketing. Although patent medicines were often prescription items, they did not have to be. The way they looked on a shelf made them so easily recognizable that even the most loutish illiterate could tell one from another. As the nostrum proprietor did so much to pioneer in advertising psychology, so he also

blazed a trail with respect to distinctive packaging. The popularity of the old English remedies, year in and year out, owed much to the fact that though the ingredients inside might vary (unbeknownst to the customer), the shape of the bottle did not. This was the reason proprietors raised such a hue and cry about counterfeiters. The secret of a formula might, if only to a degree, be retained, but simulation of bottle design and printed wrapper was easily accomplished, and to the average customer these externals were the medicine.

This fundamental fact was to be recognized by the committee of Philadelphia pharmacists in 1824. "We are aware" the committeemen reported, "that long custom has so strongly associated the idea of the genuineness of the Patent medicines, with particular shapes of the vials that contain them, and with certain printed labels, as to render an alteration in them an affair of difficulty. Many who use these preparations would not purchase British Oil that was put up in a conical vial, nor Turlington's Balsam in a cylindrical one. The stamp of the excise, the king's royal patent, the seal and coat of arms which are to prevent counterfeiters, the solemn caution against quacks and imposters, and the certified lists of incredible cures, [all these were printed on the bottle wrappers] have not even now lost their influence." Nor were they for years to come.

Thus after 1754 the Turlington Balsam bottle was pear-shaped, with sloping shoulders, and molded into the glass in crude raised capitals were the proprietor's name and his claim of THE KING'S ROYAL PATENT.⁵³ Turlington during his life had made one modification. He explained it in a broadside, saying that "to prevent the Villainy of some Persons who buying up my empty Bottles, have basely and wickedly put therein a vile spurious Counterfeit-Sort," he had changed the bottle shape. The date molded into the glass on his supply of new genuine bottles was January 26, 1754.⁵⁴ This was, perhaps, a very fine point of difference from the perspective of the average customer, and in any case the bottle was hidden under its paper wrapper.

⁵³ "From past times an original bottle of Turlington's Balsam," *Chemist and Druggist*, September 23, 1905, vol. 67, p. 525; Stewart Schackne, "Bottles," *American Druggist*, October 1933, vol. 88, pp. 78-81, 186-188, 190, 194; Frederick Fairchild Sherman, "Some early bottles," *Antiques*, vol. 3, pp. 122-123; and Stephen Van Rensselaer, *Early American bottles and flasks*, Peterborough, New Hampshire, 1926.

⁵⁴ Waldo R. Wedel and George B. Griffenhagen, "An English balsam among the Dakota aborigines," *American Journal of Pharmacy*, December 1953, vol. 126, pp. 399-415.

The British Oil bottle was tall and slender and it rested on a square base. Godfrey's Cordial came in a conical vial with steep-pitched sides, the cone's point replaced by a narrow mouth.⁵⁵ Bateman's Pectoral Drops were packaged in a more common "phial"—a tall and slender cylindrical bottle.⁵⁶ Dalby's Carminative came in a bottle not unlike the Godfrey's Cordial bottle, except that Dalby's was impressed with the inscription DALBY'S CARMINATIVE.⁵⁷ Steer's Opodeldoc bottles were cylindrical in shape, with a wide mouth; some apparently were inscribed OPODELDOC while others carried no such inscription. At least one brand of Dally's Elixir was packaged in a globular bottle, according to a picture in a 1743 advertisement.⁵⁸ Speculation regarding the size and shape of the Stoughton bottle varies.⁵⁹ At least one Stoughton bottle was described as "Round amber. Tapered from domed shoulder to base. Long 5 in. bulged neck. Square flanged mouth. Flat base."⁶⁰

Hooper's and Anderson's Scots Pills were, of course, not packaged in bottles (at least not the earliest), but were instead sold in the typical oval chip-wood pill boxes. On the lid of the box containing Hooper's Pills was stamped this inscription: DR. JOHN HOOPER'S FEMALE PILLS; BY THE KING'S PATENT 21 JULY 1713 NO. 592. So far no example or illustration of Anderson's Scots Pills has been found. At least one producer, it will be remembered (page 157), sealed the box in black wax bearing a lion rampant, three mallets argent, and the bust of Dr. Anderson.

Source of Supply Severed

On September 29, 1774, John Boyd's "medicinal store" in Baltimore followed the time-honored custom of advertising in the *Maryland Gazette* a fresh supply of medicines newly at hand from England. To this intelligence was added a warning. Since nonimportation agreements by colonial merchants were immi-

⁵⁵ Sherman, *op. cit.* (footnote 53).

⁵⁶ Schackne, *op. cit.* (footnote 53).

⁵⁷ George S. and Helen McKearin, *American glass*, New York, 1941.

⁵⁸ *Daily Advertiser*, London, October 29, 1743.

⁵⁹ George Griffenhagen, "Stodgy as a Stoughton bottle," *Journal of the American Pharmaceutical Association, Practical Pharmacy Edition*, January 1956, vol. 17, p. 20; Mitford B. Mathews, ed., *A dictionary of Americanisms on historical principles*, Chicago, 1951, 2 vols.; Bertha Kitchell Whyte, *Wisconsin heritage*, Boston, 1954; Charles Earle Funk, *Heavens to Betsy! and other curious sayings*, New York, 1955.

⁶⁰ James H. Thompson, *Bitters bottles*, Watkins Glen, New York, 1947, p. 60.



Figure 7. BOTTLES OF BRITISH OIL, 18th and early 20th century, from the Samuel Aker, David and George Kass collection, Albany, New York. (89/05-50000 photo 44201 B.)

ment, which bade fair to make goods hard to get, customers would be wise to make their purchases before the supply became exhausted. Boyd's prediction was sound. The Boston Tea Party of the previous December had evoked from Parliament a handful of repressive measures, the Intolerable Acts, and at the time of Boyd's advertisement, the first Continental Congress in session was soon to declare that all imports from Great Britain should be halted.

This Baltimore scare advertising may well have been heeded by Boyd's customers, for trade with the mother country had been interrupted before; in the wake of the Townshend Acts in 1767, when Parliament had placed import duties on various products, including tea, American merchants in various cities had entered into nonimportation agreements. Certainly, there

was a decided decrease in the Boston advertising of patent medicines received from London. With respect to imports of any kind, it became necessary to explain, and one merchant noted that his goods were "the Remains of a Consignment receiv'd before the Non-Importation Agreement took place."¹¹ When Parliament yielded to the financial pressure and abolished all the taxes but the one on tea, nonimportation collapsed. This fact is reflected in an advertisement listing nearly a score of patent medicines, including

¹¹ *M. S. A. 6.2.6.71*, Boston, December 21, 1773.

the remedies of Furlington, Bateman, the Bettons, Anderson, Hooper, Godfrey, Dally, and Stoughton, as "Just come to Hand and Warranted Genuine" on Captain Dane's ship, "directly from the Original Warehouse kept by DICKY and OKELL in Bow Street, London."⁶⁴

The days of such ample importations, however, were doomed, as commerce fell prey to the growing revolutionary agitation. The last medical advertisement in the *Massachusetts Gazette and Boston Weekly News-Letter*, before its demise the following February, appeared five months after the Battles of Lexington and Concord.⁶⁵ The apothecary at the Sign of the Unicorn was frank about the situation. He had imported fresh drugs and medicines every fall and spring up to the preceding June. He still had some on hand. Doctors and others should be advised.

Implicit in the advertisement is the suggestion that the securing of new supplies under the circumstances would be highly uncertain. That pre-war stocks did hold out, sometimes well into the war years may be deduced from a Williamsburg apothecary's advertisement.⁶¹ W. Carter took the occasion of the ending of a partnership with his brother to publish a sort of inventory. Along with the "syrup and ointment pots, all neatly painted and lettered," the crabs eyes and claws, the Spanish flies, he listed a dozen patent medicines, including the remedies of Anderson, Bateman, and Daffy.

Even the British blockade failed to prevent patent medicines from being shipped from wholesaler to retailer. In the account book of a Salem, Massachusetts, apothecary,⁶⁹ the following entry appears:

4 cases Containing	
1 Dozn Bottles Godfreys Cordial	4'
5 Dozn Do Smaller Furling Bals	18
8 Dozn Bettons British Oil	8
6 ¹ / ₂ Dozn Hoopers Female Pills	10'
4 Dozn nd 8 Boss And. Pills	10/

⁶⁴ *Ibid.*, April 25, 1771.

⁶⁵ *Ibid.*, September 7, 1775.

⁶⁶ *London Gazette*, edited by Dixon and Nicholson), Williamsburg, June 12, 1779.



Figure 8. DALBY'S CARMINATIVE, two sides of a bottle from the McKearin collection, Hoosick Falls, New York. (Smithsonian photo 44287-C.)

SALEM APRIL 8th 1777

The above 13 packages and 4 cases of medicines are ship'd on Board the Sloop Called the Two Brothers Saml West Master. On Account and [illegible word] of Mr. Oliver Smith of Boston Apothecary and to him consigned. The cases are unmarked being ship'd at Night. Error Excepted Jon. Waldo.

The sloop was undoubtedly one of the small coastal type ships employed by the colonists, and the British blockade required such ominous precautions as "unmarked cases" and "ship'd by Night."

⁶⁹ Jonathon Waldo, Apothecary account book, Salem, Massachusetts 1770-1790. Manuscript original preserved in the Library of the Essex Institute, Salem, Mass.



Figure 6. GODFREY'S CORDIAL, 18th-century bottles from the Samuel Aker, David and George Kass collection, Albany, New York. (Smithsonian photo 44201 C.)

specified that they be secured from Dicey. It will be remembered that 60 years earlier William Dicey, John Cluer, and Robert Raikes were the group of entrepreneurs who had aided Benjamin Okell in patenting the pectoral drops bearing Bateman's name. Then and throughout the century, this concern continued to operate a warehouse in the Bow Churchyard, Cheapside, London. In 1721, it was known as the "Printing-house and Picture Warehouse" of John Cluer, printer,⁷⁷ but by 1790, it was simply the "Medicinal Warehouse" of Bow Churchyard, Cheapside. This address lay in the center of the London area whence came nearly all of the British goods exported to America,⁷⁸ It had been the location of many merchants who had migrated to New England in the 17th century, and these newcomers had done business with their erst-

while associates who did not leave home. Thus were started trade channels which continued to run. The Bow Churchyard Warehouse may have been the major exporter of English patent medicines to colonial America, although others of importance were located in the same London region, in particular Robert Turlington of Lombard Street and Francis Newbery of St. Paul's Churchyard. The significance of the fact that there were key suppliers of patent medicines for the American market lies in the selection process which resulted. Out of the several hundred patent medicines which 18th-century Britain had available, Americans dosed themselves with that score or more which the major exporters shipped to colonial ports.

Not only did the Bow Churchyard Warehouse firm have Bateman's Drops. It will be remembered that in 1721 they advertised that they were preparing Dally's Elixir. In 1743, they and Newbery were made exclusive vendors of Hooper's Pills.⁷⁷ By 1750, the firm was also marketing British Oil, Anderson's Pills, and Stoughton's Elixir.⁷⁸ Turlington in 1755 was selling not only his Balsam of Life, but was also vending Dally's Elixir, Godfrey's Cordial, and Stoughton's Elixir.⁷⁹ After the tension of the Townshend Acts, it was the Bow Churchyard Warehouse which supplied a Boston apothecary with a large supply of nostrums, including all the eight patent medicines then in existence of the ten with which this discussion is primarily concerned.⁸⁰ On November 29, 1770, the *Virginia Gazette* (edited by Purdie and Dixon) reported a shipment, including Bateman's, Hooper's, Betton's, Anderson's, and Godfrey's remedies, just received "from Dr. Bateman's original wholesale warehouse in London" (the Bow Churchyard Warehouse). When Dalby's Carminative and Steer's Opodeldœ came on the market in the 1780's, it was Francis Newbery who had them for sale. Both the Newbery and Dicey (Bow Churchyard Warehouse) firms continued to operate in the post-Revolutionary years. Thus, it was no accident but rather vigorous commercial promotion over the decades, that resulted in the most popular items on the Dicey and Newbery lists appearing in the Philadelphia College of Pharmacy pamphlet published in 1824. And although the same old firms continued to export the same old medicines to the new United States, the back of the business was

⁷⁷ *Daily Advertiser*, London, September 23, 1743.

⁷⁸ "Dr. Bateman's Drops" (see footnote 7).

⁷⁹ Turlington, *op. cit.* (footnote 15).

⁸⁰ *Massachusetts Gazette*, Boston, December 21, 1769.

broken. The imitation spurred by wartime necessity became the post-war pattern.

The key recipes were to be found in formula books. Beginning in the 1790's, even American editions of John Wesley's *Primitive physic* included formulas for Daffy's, Turlington's, and Stoughton's remedies which the founder of Methodism had introduced into English editions of this guidebook to health shortly before his death.⁸¹

The homemade versions, as Jonathon Waldo had recorded (see p. 171), were about half as costly. The state of affairs at the turn of the new century is illustrated in the surviving business papers of the Beverly druggist, Robert Rantoul. In 1799 he had imported the British Oil and Essence of Peppermint bottles. In 1802 he reordered the latter, specifying that they should not have molded in the glass the words "by the Kings Patent." Rantoul wrote a formula for this nostrum in his formula book, and from it he filled 66 bottles in December 1801 and 202 bottles in June 1803. About the same time he began making and bottling Turlington's Balsam, ordering bottles of two sizes from London. His formula book contains these entries: "Jany 4th, 1804 filled 54 small turlingtons with 37 oz. Balsam," and "Jany 20th, 1804 filled 144 small turlingtons with 90¼ oz. Balsam and 9 Large Bottles with 8¼ oz."⁸²

Two decades later the imitation of the English proprietaries was even bigger business. In 1821 William A. Brewer became apprenticed to a druggist in Boston. A number of the old English brands, he recalled, were still imported and sold at the time. But his apprenticeship years were heavily encumbered with duties involving the American versions. "Many, very many, days were spent," Brewer remembered, "in compounding these imitations, cleaning the vials, fitting, corking, labelling, stamping with fac-similes of the English Government stamp, and in wrapping them, with . . . little regard to the originator's rights, or that of their heirs. . . ." The British nostrums chiefly imitated in this Boston shop were Steer's, Bateman's, Godfrey's, Dalby's, Betton's, and Stoughton's. The last was a major seller. The store loft was mostly filled with orange peel and gentian, and the laboratory had "a heavy oaken press, fastened to the



Figure 10. GODFREY'S CORDIAL, early 20th century bottles manufactured in the U. S. A. (U. S. National Museum cat. Nos. M 6089 and M 6090; Smithsonian photo 11287-B.)

wall with iron clamps and bolts, which was used in pressing out 'Stoughton's Bitters,' of which we usually prepared a hogshead full at one time." A large quantity was needed. In those days, Brewer asserted, "almost everybody indulged in Stoughton's elixir as morning bitters."⁸³

Other drugstores certainly followed the practice of Brewer's employer, in cleaning up and refilling bottles that had previously been drained of their old English medicines. The chief source of bottles to hold the American imitations, however, was the same as that to which Waldo and Rantoul had turned, English glass factories. It was not so easy for Americans to fabricate the vials as it was for them to compound the

⁸¹ John Wesley, *Primitive physic*, 21st ed., London, 1785; *ibid.*, 22nd ed., London, 1788; *ibid.*, 16th Amer. ed., Trenton, 1788; *ibid.*, 22nd Amer. ed., Philadelphia, 1791; George Dock, "The 'primitive physic' of Rev. John Wesley," *Journal of the American Medical Association*, February 20, 1915, vol. 64, pp. 629-638.

⁸² Rantoul, *op. cit.* (footnote 72).

⁸³ William A. Brewer, "Reminiscences of an old pharmacist," *Pharmaceutical Review*, August 1, 1884, vol. 4, p. 326.



Figure 11. AN ORIGINAL PACKAGE OF HOOPER'S PILLS, from the Samuel Aker, David and George Kass collection, Albany, New York. (Smithsonian photo 44201.)

contained a complaint that Americans were using calomel in the preparation of Anderson's Scots Pills, and that this practice was a deviation both from the original formula and from the different but still all-vegetable formula by which the pills were being made in England.⁸⁷ Various books were published revealing the "true" formulas, in conflicting versions.⁸⁸

Philadelphia College of Pharmacy Formulary

As the years went by and therapeutic *laissez-faire* continued to operate, conditions worsened. By the early 1820's, the old English patent medicines, whether of dwindling British vintage or of burgeoning American manufacture, were as familiar as laudanum or castor oil.

With the demand so extensive and the state of production so chaotic, the officials of the new Philadelphia College of Pharmacy were persuaded that remedial action was mandatory. In May 1822, the Board of Trustees resolved to appoint a 5-man committee "to select from such prescriptions for the preparation of Patent Medicines . . . as may be submitted to them by the members of the College, those which in their opinion, may be deemed most appropriate for the different compositions."

The committee chose for study "eight of the Patent Medicines most in use," and sought to ascertain what ingredients these ancient remedies ought by right to contain. Turning to the original formulas, where these were given in English patent specifications, the pharmacists soon became convinced that the information provided by the original proprietors served "only to mislead."

If the patent specifications were perhaps intentionally confusing, the committee inquired, how could the original formulas really be known? This quest seemed so fruitless that it was not pursued. Instead the pharmacists turned to American experience in making the English medicines. From many members of the College, and from other pharmacists as well, recipes were secured. The result was shocking. Although almost every one came bolstered with the assertion that it was true and genuine, the formulas differed so mark-

mixtures to fill them. In the years before the War of 1812, the British glass industry maintained a virtual monopoly of the specially-shaped bottles for Bate-man's, Furlington's, and the other British remedies. When in the 1820's the first titan of made-in-America nostrums, Thomas W. Dyott of Philadelphia, appeared upon the scene, this venturesome entrepreneur decided to make bottles not only for his own assorted remedies but also for the popular English brands. In time he succeeded in improving the quality of American bottle glass and in drastically reducing prices. The standard cost for most of the old English vials under the British monopoly had been \$5.50 a gross. By the early 1830's Dyott had cut the price to under two dollars.⁸⁴

Other American glass manufactories followed suit. For example, in 1835 the Free Will Glass Manufactory was making "Godfrey's Cordial," "Furlington's Balsam," and "Opodeldoc Bitters bottles."⁸⁵ An 1848 broadside entitled "The Glassblowers' List of Prices of Druggist's Ware," a broadside preserved at the Smithsonian Institution, includes listings for Furlington's Balsam, Godfrey's Cordial, Dalby's and Small and Large Opodeldoc bottles, among many other American patent medicine bottles.

In the daybook of the Beverly, Massachusetts, apothecary,⁸⁶ were inscribed for Furlington's Balsam, three separate formulas, each markedly different from the others. A Philadelphia medical journal in 1811

⁸⁴ *Domestic Production*, Philadelphia, July 1 and October 28, 1824; Thomas W. Dyott, *An exposition of the system of moral and mental culture, as practiced at the glass factory of Dyottsville*, Philadelphia, 1830; and Joseph D. Weeks, "Reports on the manufacture of Glass," *Report of the manufacturer at the United States at the tenth* . . . Washington, D. C., 1883.

⁸⁵ Van Rensselaer, *op. cit.*, (footnote 53), p. 151.

⁸⁶ Kuntz, *op. cit.* (footnote 72).

⁸⁷ *Philadelphia Medical Museum*, new ser., vol. 1, p. 130, 1811.

⁸⁸ *Formular selectar; or a collection of prescriptions of eminent physicians, and the most celebrated patent medicines*, New York, 1818; John Averton Paris, *Pharmacologia; or the history of medicinal substances, with a view to establish the art of prescribing and of composing extemporaneous formulas upon fixed and scientific principles*, New York, 1822.

edly one from the other, the committee reported a to make "the task of reformation a very difficult one." Indeed, in some cases, when two recipes bearing the same old English name were compared, they were found to contain not one ingredient in common. In other cases, the proportions of some basic ingredient would vary widely. All the formulas collected for Bateman's Pectoral Drops, for instance, contained opium, but the amount of opium to liquid ingredients in one formula submitted was 1 to 14, while in another it was 1 to 1,000.

Setting forth boldly to strip these English nostrums of "their extravagant pretensions," the committee sought to devise formulas for their composition as simple and inexpensive as possible while yet retaining the "chief compatible virtues" ascribed to them on the traditional wrappers.

Hooper's Female Pills had been from the beginning a cathartic and emmenagogue. However, only aloes was common to all the recipes submitted to the committee. This botanical, which still finds a place in laxative products today, was retained by the committee as the cathartic base, and to it were added "the Extract of Hellebore, the Sulphate of Iron and the Myrrh as the best emmenagogues."

Anderson's Scots Pills had been a "mild" purgative throughout its long career, varying in composition "according to the judgement or fancy of the preparer." Paris, an English physician, had earlier reported that these pills consisted of aloes and jalap; the committee decided on aloes, with small amounts of colocynth and gamboge, as the purgatives of choice.

Of Bateman's Pectoral Drops more divergent versions existed than of any of the others. The committee settled on a formula of opium and camphor, not unlike paragoric in composition, with catachu, anise flavoring, and coloring added. Godfrey's Cordial also featured opium in widely varying amounts. The committee chose a formula which would provide a grain of opium per ounce, to which was added saffras "as the carminative which has become one of the chief features of the medicine."

English apothecary Dalby had introduced his "Carminative" for "all those fatal Disorders in the Bowels of Infants." The committee decided that a grain of opium to the ounce, together with magnesia and three volatile oils, were essential "for this mild carminative and laxative . . . for children."

Instead of the complex formula described by Robert Turlington for his Balsam of Life, the committee settled on the official formula of Compound Tincture

of Benzoin, with balsam of peru, myrrh, and angelica root added, to produce "an elegant and rich balsamic tincture." On the other hand, the committee adopted "with slight variations, the Linimentum Saponis of the old London Dispensatory" to which they, like Steers, added only ammonia.

The committee found two distinct types of British Oil on the market. One employed oil of turpentine as its basic ingredient, while the other utilized flaxseed oil. The committee decided that both oils, along with several others in lesser quantities, were necessary to produce a medicine "as exhibited in the directions" sold with British Oil. "Oil of Bricks" which apparently was the essential ingredient of the Betton British Oil, was described by the committee as "a nauseous and unskilful preparation, which has long since been banished from the Pharmacopoeias."

Thus the Philadelphia pharmacists devised eight new standardized formulas, aimed at retaining the therapeutic goals of the original patent medicines, while brought abreast of current pharmaceutical knowledge. Recognizing that the labeling had long contained "extravagant pretensions and false assertions," the committee recommended that the wrappers be modified to present only truthful claims. If the College trustees should adopt the changes suggested, the committee concluded optimistically, then "the reputation of the College preparations would soon become widely spread, and we . . . should reap the benefit of the examination which has now been made, in an increased public confidence in the Institution and its members; the influence of which would be felt in extending the drug business of our city."¹¹

The trustees felt this counsel to be wise, and ordered 250 copies of the 12-page pamphlet to be printed. So popular did this first major undertaking of the Philadelphia College prove that in 1833 the formulas were reprinted in the pages of the journal published by the College.¹² Again the demand was high, few numbers of the publication were "more sought after," and in 1839 the formulas were printed once again, this time with slight revisions.¹³

¹¹ Philadelphia College of Pharmacy, *Transactions of the College of Philadelphia, 1821-1822*, vol. 1, pt. 1, *Proceedings of the Trustees*, Oct. 1821, *Proceedings of the Trustees*, Dec. 1821, *Proceedings of the Trustees*, May 4, 1824, Joseph W. England, ed., *Transactions of the Philadelphia College of Pharmacy, 1821-1822*, Philadelphia, 1933, p. 33.

¹² *Patent Medicines*, 7th ed., Philadelphia: Philadelphia College of Pharmacy, April 1833, xviii, 8, pp. 29-31.

¹³ C. Ellis, "Patent Medicines," *Annals of the Philadelphia College of Pharmacy*, vol. 5, pp. 67-74.

Thus had the old English patent medicines reached a new point in their American odyssey. They had first crossed the Atlantic to serve the financial interests of the men who promoted them. During the Revolution they had lost their British identity while retaining their British names. The Philadelphia pharmacists, while adopting them and reforming their character, did not seek to monopolize them, as had the original proprietors. They now could work for every man.

English Patent Medicines Go West

The double reprinting of the formulas was one token of the continuing role in American therapy of the old English patent medicines. There were others. In 1829 with the establishment of a school of pharmacy in New York City, the Philadelphia formulas were accepted as standard. The new labels devised by the Philadelphians with their more modest claims of efficacy had a good sale.⁹² It was doubtless the Philadelphia recipes which went into the Bateman and Tur-

⁹² England, *op. cit.* (footnote 89), pp. 73, 103.

lington and Godfrey vials with which a new druggist should be equipped "at the outset of business," according to a book of practical counsel.⁹³ To local merchants who lacked the knowledge or time to do it themselves, drummers and peddlers vended the medicines already bottled. "Doctor" William Euen of Philadelphia issued a pamphlet in 1840 to introduce his son to "Physicians and Country Merchants." His primary concern was dispensing nostrums bearing his own label, but his son was also prepared to take orders for the old English patent medicines.⁹⁴ Manufacturers and wholesalers of much better repute were prepared to sell bottles for the same brands, empty or filled.

⁹³ Carpenter, *op. cit.* (footnote 73).

⁹⁴ William Euen, *A short exposé on quackery . . . or, introduction of his son to physicians and country merchants*, Philadelphia, 1840.

Figure 12. ENGLISH AND AMERICAN BRANDS OF HOOPER'S FEMALE PILLS, an assortment of packages of from the Samuel Aker, David and George Kass collection, Albany, New York. (Smithsonian photo 44201 D.)



In the early 1850's a young pharmacist in upstate New York,⁹⁵ using "old alcohol barrels for tanks," worked hard at concocting Bateman's and Godfrey's and Steer's remedies. John Uri Lloyd of Cincinnati recalled having compounded Godfrey's Cordial and Bateman's Drops, usually making ten gallons in a single batch.⁹⁶ Out in Wisconsin, another druggist was buying Godfrey's Cordial bottles at a dollar for half a gross, sticking printed directions on them that cost twelve cents for the same quantity, and selling the medicine at four ounces for a quarter.⁹⁷ He also sold British Oil and Opodeldoc, the same old English names dispensed by a druggist in another Wisconsin town, who in addition kept Bateman's Oil in stock at thirteen cents the bottle.⁹⁸ Godfrey's was listed in the 1860 inventory of an Illinois general store at six cents a bottle.⁹⁹

Farther west the same familiar names appeared. Indeed, the old English patent medicines had long since moved westward with fur trader and settler. As early as 1783, a trader in western Canada, shot by a rival, called for Turlington's Balsam to stop the bleeding. Alas, in this case, the remedy failed to work.¹⁰⁰ In 1800 that inveterate Methodist traveler, Bishop Francis Asbury, resorted to Stoughton's Elixir when afflicted with an intestinal complaint.¹⁰¹ In 1808, some two months after the first newspaper began publishing west of the Mississippi River, a local store advised readers in the vicinity of St. Louis that "a large supply of patent medicines" had just been received,

⁹⁵ James Winchell Forbes, "The memoirs of an American pharmacist," *Midland Druggist and Pharmaceutical Review*, 1911, vol. 45, pp. 388-395.

⁹⁶ John Uri Lloyd, "Eclectic fads," *Eclectic Medical Journal*, October 1921, vol. 81, p. 2.

⁹⁷ Cody & Johnson Drug Co., Apothecary daybooks, Watertown, Wisconsin [1851-1872]. Manuscript originals preserved in the State Historical Society of Wisconsin, cataloged under "Cody."

⁹⁸ Swarthout and Silsbee, Druggists daybook, Columbus, Wisconsin [1852-1853]. Manuscript original preserved in the State Historical Society of Wisconsin.

⁹⁹ McClaughry and Tyler, Invoice book, Fountain Green, Illinois [1860-1877]. Manuscript original preserved in the Illinois State Historical Society, Springfield.

¹⁰⁰ Harold A. Innis, *Peter Paul, fur trader and adventurer*, Toronto, 1930.

¹⁰¹ Peter Oliver, "Notes on science, medicine and public health in the United States in the year 1800," *Bulletin of the History of Medicine*, 1934, vol. 16, p. 129.

among them Godfrey's Cordial, British Oil, Turlington's Balsam, and Steer's "Opodeldo [sic]" (17).

Turlington's product played a particular role in the Indian trade, thus demonstrating that the red man has not been limited in nostrum history to providing medical secrets for the white man to exploit. Proof of this has been demonstrated by archaeologists working under the auspices of the Smithsonian Institution in both North and South Dakota. Two pear-shaped bottles with Turlington's name and patent claims embossed in the glass were excavated by a Smithsonian Institution River Basin Surveys expedition in 1952, on the site of an old trading post known as Fort Atkinson or Fort Bethold II, situated some 16 miles southeast of the present Ellbowoods, North Dakota. In 1954 the North Dakota Historical Society found a third bottle nearby. These posts, operated from the mid-1850's to the mid-1880's, served the Hidatsa and Mandan Indians who dwelt in a town named Like-a-Fishhook Village. The medicine bottles were made of cast glass, light green in color, probably of American manufacture. More interesting is the bottle from South Dakota. It was excavated in 1923 near Mobridge at a site which was the principal village of the Arikara Indians from about 1800 to 1853, a town visited by Lewis and Clark as they ascended the Missouri River in 1804. This bottle, made of English lead glass and therefore an imported article, was unearthed from a grave in the Indian burying ground. Throughout history the claims made in behalf of patent medicines have been extreme. This Turlington bottle, however, affords one of the few cases on record wherein such a medicine has been felt to possess a postmortem utility.¹⁰²

Fur traders were still using old English patent medicines at mid-century. Four dozen bottles of Turlington's Balsam were included in an "Inventory of Stock the property of Pierre Chouteau, Jr. and Co. U [pper] Missouri." On hand at Fort Benton 4th May 1851. . . ." ¹⁰³ In the very same year, out in the new State of California, one of the early San Francisco papers listed Stoughton's Bitters as among the merchandise for sale at a general store:¹⁰⁴

¹⁰² Isaac Eisenberger, "Advertisements in the Missouri Gazette, 1808-1811," *Missouri Historical Review*, vol. 48, 1951, vol. 6, p. 27.

¹⁰³ Wedel and Graften-Keim, *Journal of Commerce* 54; A. McDonnell, *Commerce of the Missouri, 1800-1850*, *Missouri Historical Review*, 1911, vol. 19, pp. 242, 247.

¹⁰⁴ *California Democrat*, San Francisco, April 25, 1851.

Newspaper advertising of the English proprietaries – even the mere listing so common during the late colonial years – became very rare after the Philadelphia College of Pharmacy pamphlet was issued. Apothecary George J. Fischer of Frederick, Maryland, might mention seven of the old familiar names in 1837,¹⁰⁶ and another druggist in the same city might present a shorter list in 1844,¹⁰⁷ but such advertising was largely gratuitous. Since the English patent medicines had become every druggist's property, people who felt the need of such dosage would expect every druggist to have them in stock. There was no more need to advertise them than there was to advertise Luidanum or leeches or castor oil. Even the Supreme Court of Massachusetts in 1837 took judicial cognizance of the fact that the old English patent medicine names had acquired a generic meaning descriptive of a general class of medicines, names which everyone was free to use and no one could monopolize.¹⁰⁸

As the years went by, and as advertising did not keep the names of the old English medicines before the eyes of customers, it is a safe assumption that their use declined. Losing their original proprietary status, they were playing a different role. New American proprietaries had stolen the appeal and usurped the function which Bateman's Drops and Furlington's Balsam had possessed in 18th-century London and Boston and Williamsburg. As part of the cultural nationalism that had accompanied the Revolution, American brands of nostrums had come upon the scene, promoted with all the vigor and cleverness once bestowed in English but not in colonial American advertising upon Dalby's Carminative and others of its kind. While these English names retreated from American advertising during the 19th century, vast blocks of space in the ever-larger newspapers were devoted to extolling the merits of Dyott's Patent Itch Ointment, Swaim's Panacea, and Brandreth's Pills. More and more Americans were learning how to read, as free public education spread. Persuaded by the frightening symptoms and the glorious promises, citizens with a bent toward self-dosage flocked to buy the American brands. Druggists and general stores stocked them and made fine profits.¹⁰⁹ While bottles

Figure 13. OROBIDDOC BOTTLE from the collection of Mrs. Leo F. Redden, Kenmore, New York. (Smithsonian photo 44201 E.)



of British Oil sold two for a quarter in 1885 Wisconsin, one bottle of Jayne's Expectorant retailed for a dollar.¹¹⁰ It is no wonder that, although the old English names continue to appear in the mid-19th-century and later druggists' catalogs and price currents,¹¹¹ they are muscled aside by the multitude of brash American nostrums. Many of the late 19th century listings continued to follow the procedure set early in the century of specifying two grades of the various patent medicines, *i.e.*, "English" and "American," "genuine" and "imitation," "U. S." and "stamped." American manufactories specializing in pharmaceutical glassware continued to offer the various English patent medicine bottles until the close of the century.¹¹²

In a thesaurus published in 1899, Godfrey's, Bateman's, Furlington's, and other of the old English patent remedies were termed "extinct patents."¹¹³ The adjective referred to the status of the patent, not the condition of the medicines. If less prominent than in

¹⁰⁶ Cody and Johnson Drug Co., *op. cit.* (footnote 97).

¹⁰⁷ Van Schaack, Stevenson & Reid, *Annual prices current*, Chicago, 1875; Morrison, Plummer & Co., *Price current of drugs, chemicals, oils, glassware, patent medicines, druggists sundries . . .*, Chicago, 1880.

¹⁰⁸ Hagerty Bros. & Co., *Catalogue of Druggists' glassware, sundries, fancy goods, etc.*, New York, 1879; Whitall, Tatum & Co., *Annual price list*, Millville, New Jersey, 1898.

¹⁰⁹ Emil Hass, *Thesaurus of proprietary preparations and pharmaceutical specialties*, Chicago, 1899, p. 12.

¹ *Political Examiner*, Frederick, Maryland, April 19, 1837.

² *Frederick Examiner*, Frederick, Maryland, January 31, 1844.

³ *Massachusetts Supreme Court*, Thomson vs. Winchester, 19 Pick (Mass.), p. 214, March 1837.

⁴ James Harvey Young, "Patent medicines: the early post-1800 phase," *Journal of the Illinois State Historical Society*, Autumn 1953, vol. 46, pp. 254-264.

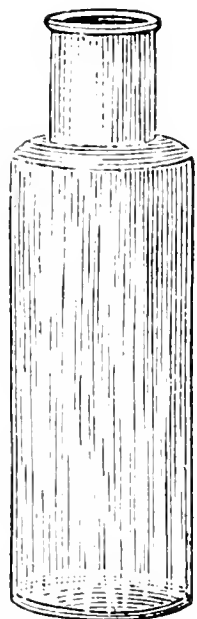


Figure 14. Orometide Borate, as illustrated in the 1879 Catalog of Hager & Bros., New York City, New York.

the olden days, the medicines were still alive. The first edition of the *National Formulary*, published in 1888, had cited the old English names as synonyms for official preparations in four cases, Dalby's, Bateman's, Godfrey's and Turlington's.

Thus as the present century opened, the old English patent medicines were still being sold. City druggists were dispensing them over their counters, and the peddler's wagon carried them to remote rural regions.¹¹⁴ But the medical scene was changing rapidly. Improvements in medical science, stemming in part from the establishment of the germ theory of disease, were providing a better yardstick against which to measure the therapeutic efficiency of proprietary remedies. Medical ethics were likewise advancing, and the occasional critic among the ranks of physicians was being joined by scores of his fellow practitioners in lambasting the brazen effrontery of the hundreds of American cure-alls which advertised from newspaper and roadside sign. Journalists joined doctors in condemning nostrums. Samuel Hopkins Adams in particular, writing "The Great American Fraud" series for *Collier's Weekly*, frightened and aroused the American public with his exposure of cheap whiskey posing as consumption cures and soothing syrups filled with opium. Then came a revolution in public policy. After a long and frustrating legislative prelude, Con-

gress in June of 1906 passed, and President Theodore Roosevelt signed, the first Pure Food and Drugs Act. The Law contained clauses aimed at curtailing the worst features of the patent medicine evil.

The Patent Medicines In The 20th Century

Although the old English patent medicines had not been the target at which disturbed physicians and "snuck-raking" journalists had taken aim, these ancient remedies were governed by provisions of the new law. In November 1906 the Bureau of Chemistry of the Department of Agriculture, in charge of administering the new federal statute, received a letter from a wholesale druggist in Evansville, Indiana. One of his stocks in trade, the druggist wrote, was a remedy called Godfrey's Cordial. He realized that the Pure Food and Drugs Act had something to do with the labeling of medicines containing opium, as Godfrey's did, and he wanted to know from the Bureau just what was required of him.¹¹⁵ Many manufacturing druggists and producers of medicine were equally anxious to learn how the law would affect them. The editors of a trade paper, the *American Druggist and Pharmaceutical Record*, issued warnings and gave advice. "It was still the custom, they noted, to wrap bottles of ancient patent medicines, like Godfrey's Cordial and Turlington's Balsam, in facsimiles of the original circulars, on which were printed extravagant claims and fabulous certificates of cures that dated back some two hundred years. The new law was not going to permit the continuation of such 18th-century practices. Statements on the Label "false or misleading in any particular" were banned.¹¹⁶

A few manufacturers, as the years went by, fell foul of this and other provisions of the law. In 1918 a Reading, Pennsylvania, firm entered a plea of guilty and received a fifty dollar fine for putting on the market an adulterated and misbranded version of Dr. Bateman's Pectoral Drops.¹¹⁷ The law required that all medicines sold under a name recognized in the *United States Pharmacopoeia* or the *National Formulary*,

¹¹⁴ Letter from Charles Fitch & Co. to Harvey Washburn, Wiley, Bureau of Chemistry, Department of Agriculture, November 2, 1906. Manuscript original in Records of the National Archives, Washington, D. C.

¹¹⁵ *Druggist and Pharmaceutical Record*, Vol. 31, No. 45, p. 513, 1906.

¹¹⁶ Department of Agriculture, Bureau of Chemistry, November 14, 1906, under the Food and Drugs Act, National Formulary, 1907, United States vs. Pabst Pure Extract Co., 1917.

¹¹⁴ Robert B. Nixon, Jr., *Corned Steaks*, New York, 1931, p. 68.

and Bateman's was included in the latter, must not differ from the standard of strength, quality, or purity as established by these volumes. Yet the Bateman Drops produced in Reading, the government charged, fell short. They contained only 27.8 percent of the alcohol and less than a tenth of the morphine that they should have had. While short on active ingredients, the Drops were long on claims. The wrapper boasted that the medicine was "effective as a remedy for all fluxes, spitting of blood, agues, measles, colds, coughs, and to put off the most violent fever; as a treatment, remedy, and cure for stone and gravel in the kidneys, bladder, and urethra, shortness of breath, straightness of the breast; and to rekindle the most natural heat in the bodies by which they restore the languishing to perfect health." Okell and Dicey had scarcely promised more. By 20th-century standards, the government asserted, these claims were false and fraudulent.

Other manufacturers sold Bateman's Drops without running afoul of the law. In 1925, ninety-nine years after the Philadelphia College of Pharmacy pamphlet was printed, one North Carolina firm was persuaded that it still was relevant to tell potential customers, in a handbill, that its Drops were being made in strict conformity with the College formula.¹¹⁸ For Compound Tincture of Opium and Gambir Compound, however, most manufacturers chose to follow the *National formulary* specifications, which remained official until 1936.

Another old English patent medicine against which the Department of Agriculture was forced to take action was Hooper's Female Pills. Between 1919 and 1923, government agents seized a great many shipments of this ancient remedy in versions put out by three Philadelphia concerns.¹¹⁹ Some of the packages bore red seals, others green seals, and still others black, but the labeling of all claimed them to be "a safe and sovereign remedy in female complaints." This theme was expanded in considerable detail and there was an 18th-century ring to the promise that the pills would work a sure cure "in all hypochondriac,

hysterick or vapourish disorders." No pill made essentially of aloes and ferrous sulphate, said the government experts, could do these things. Nor did the manufacturers, in court, seek to say otherwise. Whether the seals were green or red, whether the packages were seized in Washington or Worcester, the result was the same. No party appeared in court to claim the pills, and they were condemned and destroyed.

In one of the last actions under the 1906 law, a case concluded in 1940, after the first federal statute had been superseded by a more rigorous one enacted in 1938, two of the old English patent medicines encountered trouble.¹²⁰ They were British Oil and Dalby's Carminative, as prepared by the South Carolina branch of a large pharmaceutical manufacturing concern.

According to the label, the British Oil was made in conformity with the Philadelphia College of Pharmacy formula given in an outdated edition of the *United States dispensatory*. But instead of containing a proper amount of linseed oil, if indeed it contained any, the medicine was made with cottonseed oil, an ingredient not mentioned in the Dispensatory. Therefore, the government charged, the Oil was adulterated, under that provision of the law requiring a medicine to maintain the strength and purity of any standard it professed to follow. More than that, the labeling contravened the law since it represented the remedy as an effective treatment for various swellings, inflammations, fresh wounds, caraches, shortnesses of breath, and ulcers.

Dalby's Carminative was merely misbranded, but that was bad enough. Its label suggested that it be used especially "For Infants Afflicted With Wind, Watery Gripes, Fluxes and Other Disorders of the Stomach and Bowels," although it would aid adults as well. The impression that this remedy was capable of curing such afflictions, the government charged, was false and fraudulent. Moreover, since the Carminative contained opium, it was not a safe medicine when given according to the dosage directions in a circular accompanying the bottle. For these and several other violations of the law, the defending company, which did not contest the case, was fined a hundred dollars.

¹¹⁸ Original handbill, distributed by Standard Drug Co., Elizabeth City, North Carolina, 1925, preserved in the files of the Bureau of Investigation, American Medical Association, Chicago, Ill.

¹¹⁹ Multiple seizures were made of products shipped by the Horace B. Taylor Co., Fore & Co., and the American Synthetic Co. The quotations are from Notice of Judgment 8868; see also 8881, 8914, 8936, 8956, 8974, 9134, 9147, 9203, 9510, 9756, 9785, 10203, 10204, 10629, 11519, 11669.

¹²⁰ Federal Security Agency, Food and Drug Administration, Notice of Judgment 31134, *United States vs. McKesson and Robbins, Inc.*, Murray Division, 1942.

Throughout the 19th century, occasional criticism of the old English patent medicines had been made in the lay press. One novel¹²¹ describes a physician who comments on the use of Dalby's Carminative for babies: "Don't, for pity's sake, vitiate and torment your poor little angel's stomach, so new to the atrocities of this world, with drugs. These mixers of baby medicines ought to be fed nothing but their own nostrums. That would put a stop to their inventions of the adversary."

Opium had been lauded in the 17th and 18th centuries, when the old English proprietaries began, as a superior cordial which could moderate most illnesses and even cure some. "Medicine would be a one-armed man if it did not possess this remedy." So had stated the noted English physician, Thomas Sydenham.¹²² But the 20th century had grown to fear this powerful narcotic, especially in remedies for children. This point of view, illustrated in the governmental action concerning Dalby's Carminative, was also reflected in medical comment about Godfrey's Cordial. During 1912, a Missouri physician described the death of a baby who had been given this medicine for a week.¹²³ The symptoms were those of opium poisoning. Deploring the naming of this "dangerous mixture" a "cordial," since the average person thought of a cordial as beneficial, the doctor hoped that the formula might be omitted from the next edition of the *National formulary*. This did not happen, for the recipe hung on until 1926. The Harrison Narcotic Act, enacted in 1914 as a Federal measure to restrict the distribution of narcotics,¹²⁴ failed to restrict

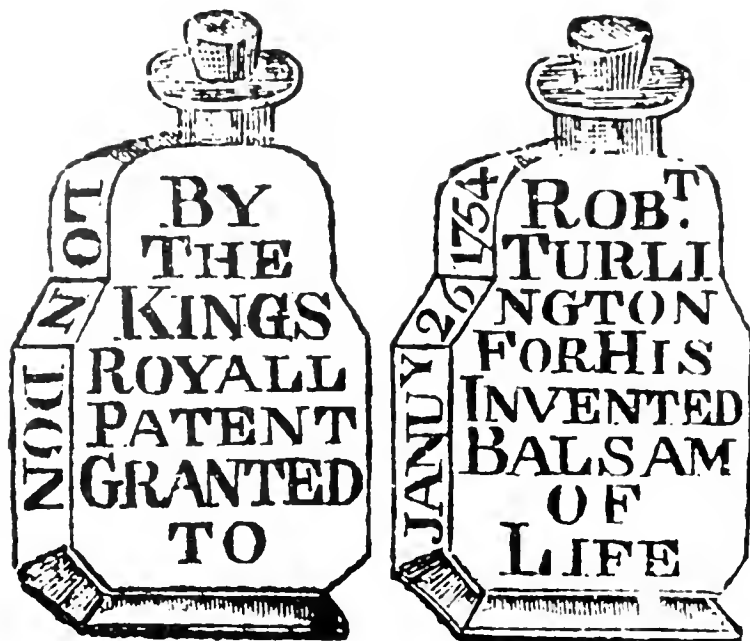


Figure 15. TURLINGTON'S BALSAM OF LIFE bottles as pictured in a brochure dated 1755-1757, preserved in the Pennsylvania Historical Society, Philadelphia, Pa. According to Turlington, the bottle was adopted in 1754 "to prevent the villainy of some persons who, buying up my empty bottles, have basely and wickedly put therein a vile spurious counterfeit sort."

the sale of many opium-bearing compounds like Godfrey's Cordial. In 1931, a Tennessee resident complained to the medical journal *Hygieia* that this medication was "sold in general stores and drug stores here without prescription and is given to babies." To this, the journal replied that the situation was "little short of criminal."¹²⁵ The charge leveled against his competitors by one of the first producers of Godfrey's Cordial two centuries earlier (see page 158) may well have proved a prophecy broad enough to cover the whole history of this potent nostrum. ". . . Many Men, Women, and especially Infants," he said, "may fall as Victims, whose Slain may exceed Herod's Cruelty . . ."

For those who persist in using the formulas of the early English patent medicines, recipes are still available. Turlington's Balsam remains as an

¹²¹ John William De Forest, *Miss Ravenel's conversion from secession to loyalty*, New York, 1867.

¹²² Charles H. LaWall, *The curious lore of drugs and medicines (Four thousand years of pharmacy)*, Garden City, New York, 1927, p. 281.

¹²³ W. B. Sissons, "Poisoning from Godfrey's Cordial," *Journal of the American Medical Association*, March 2, 1912, vol. 58, p. 650.

¹²⁴ Edward Kremers and George Urdang, *History of pharmacy*, Philadelphia, 1951, pp. 170, 278.

¹²⁵ "Godfrey's Cordial," *Hygieia*, October 1931, vol. 3, p. 1989.

unofficial synonym of U. S. P. Compound Tincture of Benzoin. Concerning its efficacy, the *United States Dispensatory*¹²⁹ states: "The tincture is occasionally employed internally as a stimulating expectorant in chronic bronchitis. More frequently it is used as an inhalent It has also been recommended in chronic dysentery . . . but is of doubtful utility."

A formula for Godfrey's Cordial, under the title of Mixture of Opium and Sassafras, is still carried in the *Pharmaceutical recipe book*.¹²⁷ *Remington's practice of pharmacy*¹²⁸ retains a formula for Dalby's Carminative under the former *National Formulary* title of Carminative Mixture.

In the nation of their origin, the continuing interest in the ancient proprietaries seems somewhat more lively than in America. The 1953 edition of *Pharmaceutical formulas*, published by the London journal *The Chemist and Druggist*, includes formulas for eight of the ten old patent medicines described in this study. This compendium, indeed, lists not one, but three different recipes for British Oil, and the formulas by which Dalby's Carminative may be compounded run on to a total of eight. Two lineal descendants of 18th-century firms which took the lead in exporting to America still manufacture remedies made so long ago by their predecessors. May, Roberts & Co., Ltd., of London, successors to the Newbery interests, continues to market Hooper's Female Pills, whereas W. Sutton & Co. (Druggists' Sundries), London, Ltd.,

of Enfield, in Middlesex, successors to Dacey & Co. at Bow Churchyard, currently sells Bateman's Pectoral Drops.¹²⁹

In America, however, the impact of the old English patent medicines has been largely absorbed and forgotten. During the past twenty years a revolution in medical therapy has taken place. Most of the drugs in use today were unknown a quarter of a century ago. Some of the newer drugs can really perform certain of the healing miracles claimed by their pretentious proprietors for the old English patent medicines.

A more recent import from Britain, penicillin, may prove to have an even longer life on these shores than did Turlington's Balsam or Bateman's Drops. Still, two hundred years is a long time. Despite the fact that these early English patent medicines are nearly forgotten by the public today, their American career is none the less worth tracing. It reflects aspects not only of medical and pharmaceutical history, but of colonial dependence, cultural nationalism, industrial development, and popular psychology. It reveals how desperate man has been when faced with the terrors of disease, how he has purchased the packaged promises offered by the sincere but deluded as well as by the charlatan. It shows how science and law have combined to offer man some safeguards against deception in his pursuit of health.

The time seems ripe to write the epitaph of the old English patent medicines in America. That they are now a chapter of history is a token of medical progress for mankind.

¹²⁹ Letter from Owen H. Waller, editor of *The Chemist and Druggist*, to George Griffenhagen, January 15, 1957.

Figure 16. TURLINGTON'S BALSAM OF LIFE BOTTLE (all four sides) found in an Indian grave at Moberg, South Dakota; now preserved in the U. S. National Museum. (Cat. No. 32462, *Archaeol.*; Smithsonian photo 42036 A.)



CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 11

WHY BEWICK SUCCEEDED:
A NOTE IN THE HISTORY OF WOOD ENGRAVING

Jacob Kainen

THE CONTEMPORARY VIEW OF BEWICK	186
LOW STATUS OF THE WOODCUT	188
WOODCUT AND WOOD ENGRAVING	189
WOOD ENGRAVING AND THE STEREOTYPE	197

WHY BEWICK SUCCEEDED:

A Note in the History of Wood Engraving

Thomas Bewick has been acclaimed as the pioneer of modern wood engraving whose genius brought this popular medium to prominence. This study shows that certain technological developments prepared a path for Bewick and helped give his work its unique character.

THE AUTHOR: *Jacob Kainen is curator of graphic arts, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.*

By Jacob Kainen

NO OTHER ARTIST has approached Thomas Bewick (1753-1828) as the chronicler of English rustic life. The little wood engravings which he turned out in such great number were records of typical scenes and episodes, but the artist could also give them social and moral overtones. Such an approach has attracted numerous admirers who have held him in esteem as an undoubted homespun genius. The fact that he had no formal training as a wood engraver, and actually never had a lesson in drawing, made his native inspiration seem all the more authentic.

The Contemporary View of Bewick

After 1790, when his *A general history of quadrupeds* appeared with its vivid animals and its humorous and mordant tailpiece vignettes, he was hailed in terms that have hardly been matched for adulation. Certainly no mere book illustrator ever received equal acclaim. He was pronounced a great artist, a great man, an outstanding moralist and reformer, and the master of a new pictorial method. This flood of eulogy rose increasingly during his lifetime and continued throughout the remainder of the 19th century. It came from literary men and women who saw him as the artist of the common man; from the pious who recognized him as a commentator on the vanities and hardships of life (but who sometimes deplored the frankness of his subjects); from bibliophiles who wel-

comed him as a revolutionary illustrator; and from fellow wood engravers for whom he was the indispensable trail blazer.

During the initial wave of Bewick appreciation, the usually sober Wordsworth wrote in the 1805 edition of *Lyrical ballads*:¹

O now that the genius of Bewick were mine,
And the skill which he learned on the banks of the Tyne!
Then the Muses might deal with me just as they chose,
For I'd take my last leave both of verse and of prose.
What feats would I work with my magical hand!
Book learning and books would be banished the land.

If art critics as a class were the most conservative in their estimates of his ability, it was one of the most eminent, John Ruskin, whose praise went to most extravagant lengths. Bewick, he asserted, as late as 1890,² "... without training, was Holbein's equal ... in this frame are set together a drawing by Hans Holbein, and one by Thomas Bewick. I know which is most scholarly; but I do *not* know which is best." Linking Bewick with Botticelli as a draughtsman, he added:³ "I know no drawing so subtle as Bewick's since the fifteenth century, except Holbein's and Turner's." And as a typical example of popular appreciation, the following, from the June 1828 issue

¹ William Wordsworth, *Lyrical ballads*, London, 1805, vol. 1, p. 199.

² John Ruskin, *Ariadne Florentina*, London, 1890, pp. 98, 99.

³ *Ibid.*, p. 246.

of *Blackwood's Magazine*, appearing a few months before Bewick's death, should suffice:

Have we forgotten, in our hurried and imperfect enumeration of wise worthies, have we forgotten "The Genius that dwells on the banks of the Tyne," the matchless, Inimitable Bewick? No. His books lie in our parlour, dining-room, drawing-room, study-table, and are never out of place or time. Happy old man! The delight of childhood, manhood, decaying age! A moral in every tail-piece—a sermon in every vignette.

This acclaim came to Bewick not only because his subjects had a homely honesty, but also, although not generally taken into account, because of the brilliance and clarity with which they were printed. Compared with the wood engravings of his predecessors, his were more detailed and resonant in black and white, and accordingly seemed miraculous and unprecedented. He could engrave finer lines and achieve better impressions in the press because of improvements in technology which will be discussed later, but for a century the convincing qualities of this new technique in combination with his subject matter led admirers to believe that he was an artist of great stature.

Later, more mature judgment has made it plain that his contributions as a craftsman outrank his worth as an artist. He was no Holbein, no Botticelli—it is absurd to think of him in such terms—but he did develop a fresh method of handling wood engraving. Because of this he represents a turning point in the development of this medium which led to its rise as the great popular vehicle for illustration in the 19th century. In his hands wood engraving underwent a special transformation; it became a means for rendering textures and tonal values. Earlier work on wood could not do this; it could manage only a rudimentary suggestion of tones. The refinements that followed, noticeable in the highly finished products of the later 19th century, came as a direct and natural consequence of Bewick's contributions to the art.

Linton⁴ and a few others object to the general claim that Bewick was the reviver or founder of modern wood engraving, not only because the art was practiced earlier, if almost anonymously, and had never really died out, but also because his bold cuts had little in common with their technician's concern with infinite manipulation of surface tones, a feature of later work. But this misses the main

⁴William Linton, *The masters of wood engraving*, London, 1889, p. 133.

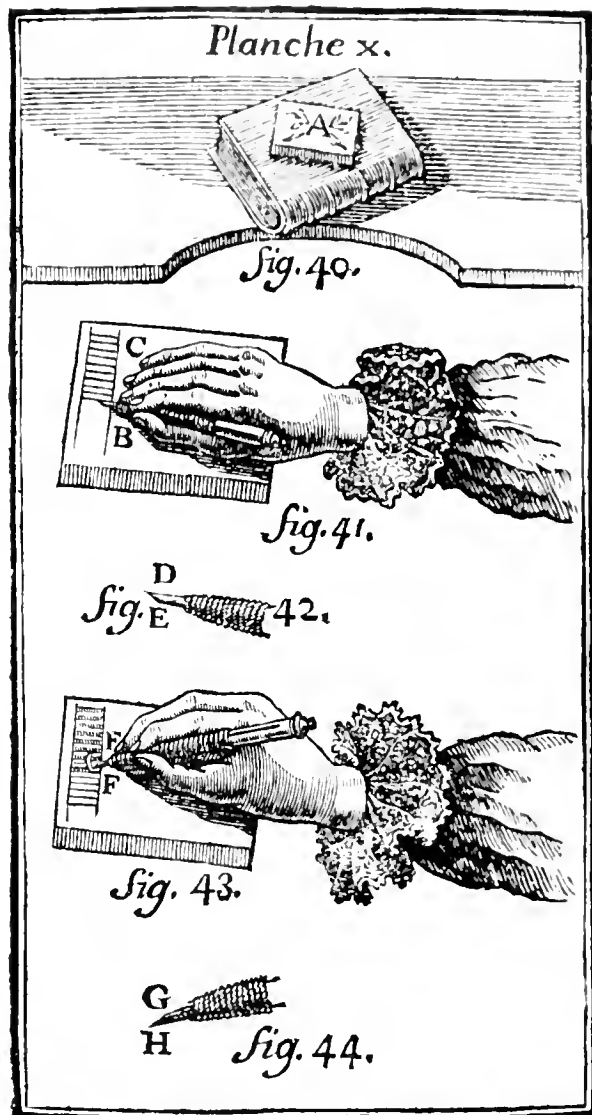


Figure 1. WOODCUTTING PROCEDURE, showing method of cutting with the knife on the plank grain, from Jean Papillon's *Traité de la gravure en bois*, 1766.

point—that Bewick had taken the first actual steps in the new direction.

Unquestionably he gave the medium a new purpose, even though it was not generally adopted until after 1850. Through his pupils, his unrelenting industry, and his enormous influence he fathered a pictorial activity that brought a vastly increased quantity of illustrations to the public. Periodical literature, spurred by accompanying pictures that could be cheaply made, quickly printed, and dramatically pointed, became a livelier force in education. Text-

books, trade journals, dictionaries, and other publications could more effectively teach or describe; scientific journals could include in the body of text neat and accurate pictures to enliven the pages and illustrate the equipment and procedures described. Articles on travel could now have convincingly realistic renditions of architectural landmarks and of foreign sights, customs, personages, and views. The wood engraving, in short, made possible the modern illustrated publication because, unlike copper plate engraving or etching, it could be quickly set up with printed matter. Its use, therefore, multiplied increasingly until just before 1900, when it was superseded for these purposes by the photomechanical halftone.

But while Bewick was the prime mover in this revolutionary change, little attention has been given to the important technological development that cleared the way for him. Without it he could not have emerged so startlingly; without it there would have been no modern wood engraving. It is not captious to point out the purely industrial basis for his coming to prominence. Even had he been a greater artist, a study of the technical means at hand would have validity in showing the interrelation of industry and art although, of course, the aesthetic contribution would stand by itself.

But in Bewick's case the aesthetic level is not particularly high. Good as his art was, it wore an everyday aspect; he did not give it that additional expressive turn found in the work of greater artists. It should not be surprising, then, that his work was not inimitable. It is well-known that his pupils made many of the cuts attributed to him, making the original drawings and engraving in his style so well that the results form almost one indistinguishable body of work. The pupils were competent but not gifted, yet they could turn out wood engravings not inferior to Bewick's own. And so we find that such capable technicians as Nesbit, Clennell, Robinson, Hole, the Johnsons, Harvey, and others all contributed to the Bewick cult.

Linton, who worshipped him as an artist but found him primitive as a technician, commented: ⁵ "Widely praised by a crowd of unknowing connoisseurs and undiscriminating collectors, we have yet, half a century after his death, to point out how much of what is attributed to him is really by his hand."

Chatto,⁶ who obtained his information from at least one Bewick pupil, says that many of the best tailpieces in the *History of British birds* were drawn by Robert Johnson, and that "the greater number of those contained in the second volume were engraved by Clennell." Granted that the outlook and the engraving style were Bewick's, and that these were notable contributions, the fact that the results were so close to his own points more to an effective method of illustration than to the outpourings of genius.

Low Status of the Woodcut

Bewick's training could not have been less promising. Apprenticed to Ralph Beilby at the age of fourteen, he says of his master:⁷

. . . The work-place was filled with the coarsest kind of steel-stamps, pipe moulds, bottle moulds, brass clock faces, door plates, coffin plates, bookbinders letters and stamps, steel, silver and gold seals, mourning rings, &c. He also undertook the engraving of arms, crests and cyphers, on silver, and every kind of job from the silversmiths; also engraving bills of exchange, bank notes, invoices, account heads, and cards . . . The higher department of engraving, such as Landscapes or historical plates, I dare say, was hardly thought of by my master . . .

A little engraving on wood was also done, but Bewick tells us that his master was uncomfortable in this field and almost always turned it over to him. His training, obviously, was of a rough and ready sort, based upon serviceable but routine engraving on metal. There was no study of drawing, composition, or any of the refinements that could be learned from a master who had a knowledge of art. Whatever Bewick had of the finer points of drawing and design he must have picked up by himself.

When he completed his apprenticeship in 1774 at the age of twenty-one, the art of engraving and cutting on wood was just beginning to show signs of life after more than a century and a half of occupying the lowest position in the graphic arts. Since it could not produce a full gamut of tones in the gray register, which could be managed brilliantly by the copper plate media—line engraving, etching, mezzotint and aquatint—it was confined to ruder and less exacting uses, such as ornamental headbands and tailpieces for printers and as illustrations for cheap popular broadsides. When good illustrations

⁵ William Chatto, and John Jackson, *A treatise on wood engraving*, London, 1861 (1st ed. 1839), pp. 496-498.

⁷ Thomas Bewick, *Memoir of Thomas Bewick*, New York, 1925 (1st ed. London, 1862), pp. 50, 51.

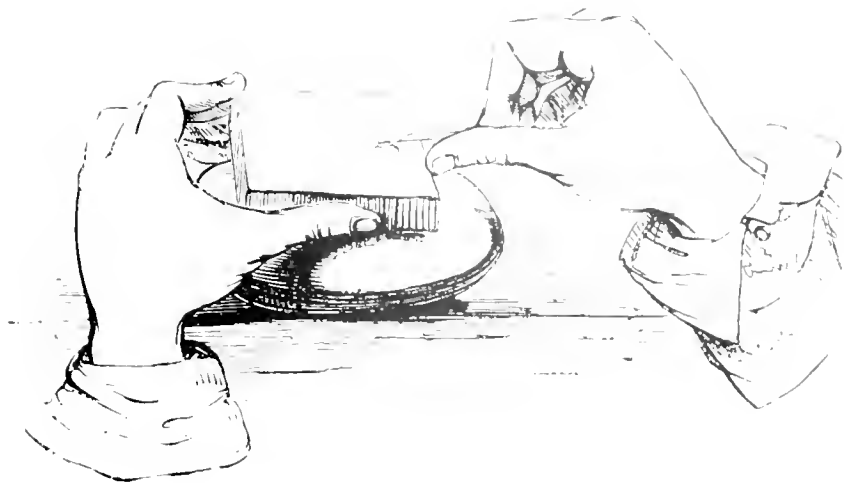


Figure 2. WOOD ENGRAVING PROCEDURE, showing manipulation of the burin, from Chatto and Jackson, *Treatise on wood engraving*, 1861. (See footnote 6.)

were needed in books and periodicals, copper plate work was almost invariably used, despite the fact that it was more costly, was much slower in execution and printing, and had to be bound in with text in a separate operation. But while the Society of Arts had begun to offer prizes for engraving or cutting on wood (Bewick received such a prize in 1775) the medium was still moribund. Dobson⁵ described its status as follows:

During the earlier part of the eighteenth century engraving on wood can scarcely be said to have flourished in England. It existed—so much may be admitted—but it existed without recognition or importance. In the useful little *Etat des Arts en Angleterre*, published in 1757 by Roquet the enameller, a treatise so catholic in its scope that it included both cookery and medicine, there is no reference to the art of wood-engraving. In the *Artist's Assistant*, to take another book which might be expected to afford some information, even in the fifth edition of 1783, the subject finds no record, even though engraving on metal, etching, mezzotinto-scraping—to say nothing of “painting on silks, satins, etc.” are treated with sufficient detail. Turning from these authorities to the actual woodcuts of the period, it must be admitted that the survey is not encouraging.

Earlier, among other critics of the deficiencies of the woodcut, Horace Walpole⁶ had remarked:

I have said, and for two reasons, shall say little of wooden cuts: that art never was executed with any perfection in

⁵ Austin Dobson, *Thomas Bewick and his pupils*, Boston, 1883, pp. 1, 2.

⁶ Horace Walpole, *Anecdotes of painting in England: A catalogue of engravers who have been born, or resided in England. Drawn from the manuscript of Mr. George Vertue*, London, 1757 (1st ed. 1762), p. 4.

England; engraving on metal was a final improvement of the art, and supplied the defects of cuttings in wood. The ancient wooden cuts were certainly carried to a great height, but that was the merit of the masters, not of the method.

Woodcut and Wood Engraving

It is necessary, before continuing, to distinguish clearly between the woodcut and the wood engraving, not only because early writers used these terms interchangeably, but also to determine exactly what Bewick contributed technically. The woodcut began with a drawing in pen-and-ink on the plank surface of a smooth-grained wood such as pear, serviceberry, or box. The woodcutter, using knife, gonges, and chisels, then lowered the wood surrounding the lines to allow the original drawing, unaltered, to be isolated in relief (see fig. 1). Thus the block, when inked and printed, produced facsimile impressions of the drawing in black lines on white paper. Usually an accomplished artist made the drawing, whereas only a skilled craftsman was needed to do the cutting; very few cutters were also capable of making their own drawings.

The wood engraving, on the other hand, started with a section of dense wood of a uniform texture, usually box or maple, and with the end-grain rather than the plank as surface. For larger engravings a number of sections were mortised together. The drawing was made on the block, not in pen-and-ink although this could be done; certain types of wood engraving reproduced pen drawings—but in gray washes with a full range of tones. The engraver, using a burin similar to that employed in copper plate work, then ploughed



Figure 3. LATE 15TH-CENTURY WHITE-LINE ENGRAVING "The crowning of the Virgin," in the "dotted manner" executed on metal for relief printing. Parts were hand colored.

out wood in delicate ribbons (see fig. 2). Since the surface was to receive ink, the procedure moved from black to white: the more lines taken away, the lighter the tones would appear, and, conversely, where fewest or finest lines were removed the tones would be the darkest. In the finished print the unworked surface printed black while each of the engraved lines showed as white. It was the "white line" that gave wood engraving its special quality. On the smoother end-grain it could be manipulated with extreme fineness, an impossibility with the plank side, which would tear slightly or "feather" when the burin was moved across the grain. Tones and textures approaching the scale of copper plate engraving could be created, except, of course, that the lines were white and the impressions not so brilliant. But since grays were achieved by the visual synthesis of black ink and white paper, it mattered little whether the engraved lines were black or white so long as the desired tones could be produced.

For purposes of realism, this was an enormous improvement over the old black-line woodcut. Natural tones and textures could be imitated. The engraver was no longer a mere mechanical craftsman cutting around existing lines; special skill was needed to translate tones in terms of white lines of varying thickness and spacing. The opportunity also existed for each engraver to work his own tones in his own manner, to develop a personal system. In short, the medium served the same purpose as copper plate line engraving, with the added virtue that it could be printed together with type in one impression. If it failed artistically to measure up to line engraving or to plank woodcut, this was not the fault of the process but of the popular reproductive ends which it almost invariably served.

Actually, white-line engraving for relief printing dates from the 15th century. The most conspicuous early examples are the so-called "dotted prints" or "gravures en manière criblée," in which the designs were brought out by dots punched in the plates, and by occasional engraved lines (see fig. 3). Until Koehler's¹⁰ study made this fact plain, 19th-century critics could hardly believe that these were merely white-line metal relief prints, inked on the surface like woodcuts. But a number of other examples of the same period exist which were also made directly on copper or type metal—the method, although rudimentary, being similar in intent to 19th-century wood engraving. One of these examples (fig. 4), in the collection of the U. S. National Museum, is typical. This was not simply an ordinary line engraving printed in relief rather than in the usual way; the management of the lights shows that it was planned as a white-line engraving. The reason for this treatment, obviously, was to permit the picture and the type to be printed in one operation.

The well-known wood engravings of soldiers with standards, executed by Urs Graf in the early 1500's, are probably the only white-line prints in this medium by an accomplished artist until the 18th century. But these are mainly in outline, with little attempt to achieve tones. No advantage was gained by having the lines white rather than black other than an engaging roughness in spots; the prints were simply whimsical excursions by an inventive artist.

¹⁰Sylvester R. Koehler, "White-line engraving for relief-printing in the fifteenth and sixteenth centuries," in *Annual report of the . . . Smithsonian Institution . . . for the year ending June 30, 1890, report of the U. S. National Museum, Washington, 1892*, pp. 385-389.

Pomerium quadragesimale.

fratris Pelbarti ordinis
sancti Francisci



Figure 4.—WHILE-LINE ENGRAVING ON METAL FOR RELIEF PRINTING. "The Franciscan Pelbart of Temesvár, Studying in a Garden," from *Pomerium quadragesimale fratris Pelbarti ordinis sancti Francisci*, Augsburg, 1502.

Relief engraving on type metal and end-grain wood really got under way as a consistent process in England at the beginning of the 18th century. Chatto¹¹ gives this date as conjecture, without actual evidence, but a first-hand account can be found in the rare and little-known book, published in 1752, in which the combination of anonymous authorship and a misleading title obscured the fact that it is a digest of John Baptist Jackson's manuscript journal. This eminent woodcutter, who was born about 1700 and worked in England during the early years of the century, must be considered an important and reliable witness. The unknown editor paraphrases Jackson on the subject of engraving for relief purposes:¹²

... I shall give a brief Account of the State of Cutting on Wood in *England* for the Type Press before he [Jackson] went to *France* in 1725. In the beginning of this Century a remarkable Blow was given to all Cutters on Wood, by an Invention of engraving on the same sort of Metal which Types are cast with. The celebrated Mr. *Kirkhal*, an able Engraver on Copper, is said to be the first who performed a Relievo Work to answer the use of Cutting on Wood. This could be dispatched much sooner, and consequently answered the purpose of Booksellers and Printers, who purchased those sort of Works at a much cheaper [sic] Rate than could be expected from an Engraver on Wood; it required much more Time to execute with accuracy any piece of Work of the same Measure with those carved on Metal. This performance was very much in Vogue, and continued down to this Day, to serve for Initials, Fregii and Finali; it is called a clear Impression, but often gray and hazy, far from coming up to that clear black Impression produced with cutting on the side of a piece of Box-wood or Pear-tree. Much about the same time there started another Method of Engraving on the end ways of Wood itself, which was cut to the height of the Letters to accompany them in the Press, and engraved in the same Manner as the Metal Performance; this Method was also encouraged, and is the only way of Engraving on Wood at present used in the English Printing-houses. These performances are to be seen in Magazines, News Papers, &c. and are the Remains of the ancient Manner of Cutting on Wood, and is the reason why the Curious concluded it was intirely lost.

This is important evidence that end-grain wood engraving was not only known in England in the early 18th century but was actually the prevailing style. In that country, where a woodcut tradition did



Figure 5. EXAMPLE OF THE WOODCUT STYLE THAT CREATED FACSIMILE DRAWINGS. Woodcut (actual size) by Hans Lutzellburger, after a drawing by Holbein for his "Dance of Death," 1538.

not exist, the new method gained its first foothold. But it was not yet conceived in terms of white lines; it was merely a cheaper substitute for cutting with the knife on the plank. In European countries with long art and printing traditions, this substitute method was considered beneath contempt. Jackson¹³ describes the aversion of French woodcutters for the newer and cheaper process:

From this Account it is evident that there was little encouragement to be hoped for in *England* to a Person whose Genius led him to prosecute his Studies in the ancient Manner; which obliged Mr. *Jackson* to go over to the Continent, and see what was used in the Parisian Printing-houses. At his arrival there he found the *French* engravers on Wood all working in the old Manner; no Metal engravers, or any of the same performance on the end of the Wood, was ever used or countenanced by the Printers or Booksellers in that City.

There were good reasons for the lack of development of a white-line style, even in England with its lower standards in printing and illustrative techniques. On the coarse paper of the period line white lines could not be adapted to relief (typographical) presswork; they would be lost in printing because the ribbed paper received ink unevenly. Even the simple black

¹¹ Chatto, *op. cit.* (footnote 6), p. 446.

¹² *Journal, or the origin of printing in Europe, by a lover of art*, London, 1752, pp. 25, 26.

¹³ *Ibid.*, p. 27.

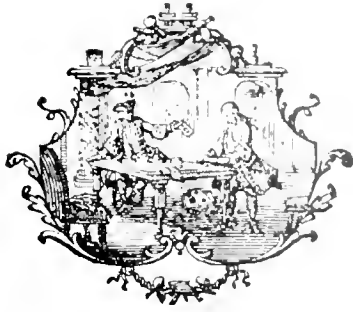


Figure 6. WOODCUT LAID OUT BY J. M. PAPILLON, from *Traité historique et pratique de la gravure en bois*, 1766. The cutting was done so minutely that some details were lost in printing. (Actual size.)

lines of the traditional woodcut usually printed spottily when combined with type. The white lines, then, had to be broadly separated. This did not permit the engraving of delicate tones. If this could not be achieved, the effect was similar to woodcutting but with less crispness and accuracy in the drawing. A good woodcut in the old manner could do everything the wood engraving could do, before Bewick, with the added virtue that the black line was comparatively clear and unequivocal, as can be seen in figure 5.

The woodcut, in the hands of a remarkable cutter, could produce miracles of delicacy. It could, in fact, have black lines so fine and so closely spaced as to take on the character of line engraving. It did not, of course, have the range of tones or the delicacy of modeling possible in the copper plate medium, where every little trench cut by the burin would hold ink below the wiped-off surface, to be transferred to dampened paper under the heavy pressure of the cylinder press. In addition, the roughness of early paper, which was serious for the woodcut, created no difficulties for the line engraver or for other workers in the intaglio or gravure media.

But the influence of copper plate work was strong, and some skillful but misguided woodcut craftsmen tried to obtain some degree of its richness. French artists from about 1720, notably Jean M. Papillon, produced cuts so delicate that their printing became a problem (see fig. 6). Jackson, who had worked with the French artist in Paris, condemned his efforts to turn the woodcut into a tonal medium through the creation of numerous delicate lines because such effects

were impossible to copy. Jackson, *Journal of Engraving and the Etcher*.

In 1728 Mr. Papillon, a Gentleman Printer, Aldershot, wherein is placed Cuts, done in Wood, almost a Year, with the Signs of the Zodiac, in such a Minute Style, that he seems to forget in that Work the Impossibility of printing it in a Press with any Clearness. . . . By alas! His father and Mr. . . . also woodcutters, had examined Impression and its Process, and saw how careful the Ancients were to keep a proper Distance between their Lines, and hatched Works, so as to produce a clean Impression. . . . I saw the Almanack in a horrid Condition before I left Paris, the Signs of the Zodiac were like a Blotch, notwithstanding the utmost Care and Diligence the Printer used to take up very little Ink to keep them clean.

It is clear that too thin a strip of white between black lines was not suitable for printing in the first half of the 18th century. But when Bewick's cuts after 1790 are examined we can see many white lines thinner than a hair. Obviously something had happened to permit him a flexibility not granted to earlier workers on wood. Bewick's whole craft depended upon his ability to control white lines of varying thickness. Why was he able to do this, and why could it be done without trouble by others after him?

Early paper, as already mentioned, had a ribbed grain because it was made on a hand mould in which wires were closely laid in one direction, but with enough space between to allow the water in the paper pulp to drain through. Crossing wires, set some distance apart, held them together. Each wire, however, made a slight impression in the finished paper, the result being a surface with minute ripples. The surface of this laid paper presented irregularities even after the glazing operation, done with hammers before about 1720 and with wooden rollers up to about 1825.

In 1756 James Whatman began to manufacture a new, smooth paper to replace the laid variety that had been used since the importation of paper into Europe in the 12th century. Whether Whatman or the renowned printer John Baskerville was the guiding spirit in this development is uncertain. Baskerville,

¹ Jackson, *Journal*, footnote 12, p. 8.

² David Hunter, *The Book of the Guild of St. Andrew* (New York, 1939), pp. 148, 181.

³ A. T. Hazen, "Baskerville and the Laid-Watermark Paper of Baskerville, *Journal of the Society of Book Collectors*, 1913, 1: 52-5. For a brilliant study of the Watermark paper practically all wove paper of the 18th century, see the journal of the Thomas Balston Society, *Book Collector*, 1936, 1: 36-8, 45.

who had been experimenting with type faces of a lighter and more delicate design, had been dissatisfied with the uneven surface of laid paper. Possibly he saw examples of the Chinese wallpaper on wove stock, made from a cloth mesh, which was a staple of the trade with the Orient. Hunter¹⁷ describes the new mould:

The wove covering was made of fine brass screening and received its name because it was woven on a loom in about the same manner as cloth. It left in the paper an indistinct impression resembling a fabric. Baskerville had been in the japanning and metal-working trades before becoming a printer, so that he was naturally familiar with this material, metal screening having been used in England for other purposes before it was put to use as a material upon which to mould sheets of paper.

The first book printed in Europe on wove paper unquestionably was the Latin edition of Virgil produced by Baskerville in 1757. This was, however, partly on laid also. The actual paper was made in James Whatman's mill in Maidstone, Kent, on the banks of the river Len, where paper had been made since the 17th century. Whatman, who became sole owner of the mill in 1740, specialized in fine white paper of the highest quality. But while the book attracted considerable attention it did not immediately divert the demand for laid paper, since it was looked on more as an oddity than as a serious achievement. Baskerville was strictly an artist; he took unlimited time and pains, he had no regard for the prevailing market, and he produced sporadically; also, he was harshly criticized and even derided for his strange formats.¹⁸ With such a reputation for impracticality the printer's influence was negligible during his lifetime although, of course, it was widely felt later.

About 1777 the French became acquainted with wove paper, which Franklin brought to Paris for exhibition. In 1779, according to Hunter,¹⁹ M. Didot the famous printer, "having seen the *papier vélin* that Baskerville used, addressed a letter to M. Johannot of Annonay, a skilled papermaker, asking him to endeavour to duplicate the smooth and even surface of this new paper. Johannot was successful in his ex-



Figure 7. WOOD ENGRAVING BY THOMAS BEWICK, "The Man and the Flea," for *Fables, by the late Mr. Gay*, 1779. (Actual size.) Note how the closely worked lines of the sky and water have blurred in printing on laid paper. The pale vertical streak is caused by the laid mould.

periments, and for his work in this field he was in 1781 awarded a gold medal by Louis XVI."

Wove paper was so slow to come into use that Jenkins gives the date 1788 for its first appearance in book printing.²⁰ While he missed a few examples, notably by Baskerville, it is certain that few books with wove paper were published before 1790. But after that date its manufacture increased with such rapidity that by 1805 it had supplanted laid paper for many printing purposes.

The reasons for this gap between the introduction and the acceptance of the new paper are not clear; the inertia of tradition as well as the probable higher cost no doubt played a part, and we may assume that early wove paper had imperfections and other drawbacks serious enough to cause printers to prefer the older material.

Bewick's early work was printed on laid paper. Up to 1784 he had worked in a desultory fashion on wood, much of his time being occupied with seal cutting because there was still no real demand for wood engraving. In Gay's *Fables*, published in 1779, the cuts printed so poorly on the laid paper (see fig. 7) that Dobson²¹ was moved to say:

Generally speaking, the printing of all these cuts, even in the earlier editions (and it is absolutely useless to consult

¹⁹ Rhys Jenkins, "Early papermaking in England, 1495-1788," *Library Association Record*, London, 1900-1902, vol. 2, nos. 9 and 11; vol. 3, no. 5; vol. 4, nos. 3 and 4.

²¹ Dobson, *op. cit.* (footnote 8), p. 56.

¹⁷ Hunter, *op. cit.* (footnote 15), p. 215.

¹⁸ R. Straus and R. K. Dent, *John Baskerville*, Cambridge, 1907. On page 19 the authors include a letter to Baskerville from Benjamin Franklin, written in 1760 in a jocular tone, which notes that he overheard a friend saying that Baskerville's types would be "the means of blinding all the Readers in the Nation owing to the thin and narrow strokes of the letters."

¹⁹ Hunter, *op. cit.* (footnote 15), p. 219.

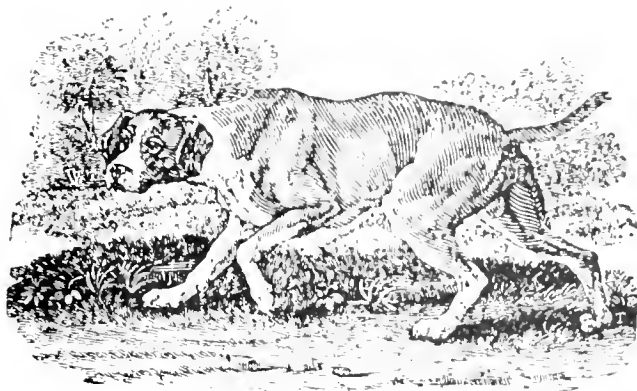


Figure 8. THE SPANISH POINTER (Illustration actual size) by Thomas Bewick, from *A general history of quadrupeds*, 1796, in the collections of the Library of Congress.

any others), is weak and unskillful. The fine work of the backgrounds is seldom made out, and the whole impression is blurred and unequal.

Even in the *Select fables of Aesop and others* of 1784, when Bewick's special gifts began to emerge, the cuts on laid paper appeared weak in comparison with his later work. Bewick was still using wood engraving as a cheaper, more quickly executed substitute for the woodcut. The designs were based upon Croxall's edition of *Aesop's Fables*, published in 1722, which was probably the best and most popular illustrated book published in England during the century up to Bewick's time. According to Chatto, the cuts were made with the burin on end-grain wood, probably by Kirkall,²² but Bewick believed they were engraved on type metal.²³ It was not easy to tell the difference. Type metal usually made graver impressions than wood and sometimes, but not always, nail-head marks appeared where the metal was fastened to the wood base. The Croxall cuts, in turn, were adapted with little change from 17th-century sources—etchings by Francis Barlow and line engravings by Sebastian Le Clerc. Bewick's cuts repeated the earlier designs but changed the locale to the English countryside of the late 18th century. This was to be expected: to have a contemporary meaning the actors of the old morality play had to appear in modern dress and with up-to-date scenery. But technically the cuts followed the pattern of Croxall's wood engraver, although with a slightly greater range of tone. Artistically Bewick's interpretation was inferior because it was more literal; it lacked the grander feeling of the earlier work.

Bewick really became the prophet of a new pictorial style in his *A general history of quadrupeds*, published in

1790 on wove paper (see figs. 8, 9, and 10). Here his animals and little vignetted tailpieces of observations in the country announced an original subject for illustration and a fresh treatment of wood engraving, although some designs were still copied from earlier models. The white line begins to function with greater elasticity; tones and details beyond anything known previously in the medium appear with the force of innovation. The paper was still somewhat coarse and the cuts were often gray and muddy. But the audacity of the artist in venturing tonal subtleties was immediately apparent.

One of Bewick's old friends at Newcastle had been William Bulmer, who by the 1790's had become a famous printer. In 1795 he published an edition of *Poems by Goldsmith and Parry*, which was preceded by an Advertisement announcing his intentions:

The present volume . . . [is] particularly meant to combine the various beauties of PRINTING, TYPE-FOUNDING, ENGRAVING, and PAPER-MAKING. . . . The ornaments are all engraved on blocks of wood, by two of my earliest acquaintances, Messrs. Bewick, Thomas and his brother and apprentice John, of Newcastle upon Tyne and London, after designs made from the most interesting passages of the Poems they embellish. They have been executed with great care, and I may venture to say, without being supposed to be influenced by ancient friendship, that they form the most extraordinary effort of the art of engraving upon wood that ever was produced in any age, or any country. Indeed it seems almost impossible that such delicate effects could be obtained from blocks of wood. Of the Paper, it is only necessary to say that it comes from the manufactory of Mr. Whatman.

The following year, 1796, a companion volume, *The Grasshopper*, by William Somervile, appeared with cuts by Bewick after drawings by his brother John (see fig. 11). In both books, although no acknowledgment was given, there was considerable assistance

²² Chatto, *op. cit.* (footnote 6), p. 148.

²³ Thomas Bewick, *Fables of Aesop* (London, Newcastle, 1818).

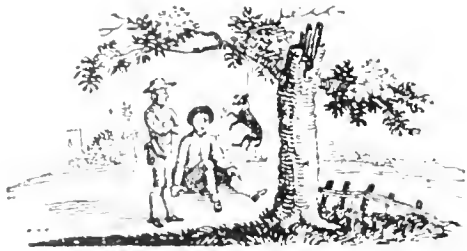


Figure 9. LAMPREY, BY THOMAS BEWICK (actual size), from *A general history of quadrupeds*, 1790, in the collections of the Library of Congress.

from pupils Robert and John Johnson and Charlton Nesbit, as well as from an artist associate Richard Westall.²⁴ Bulmer was quite conscious that a new era in printing and illustration had begun. Updike²⁵ notes Bulmer's recognition of the achievements of both Baskerville and Bewick in giving the art of printing a new basis:

To understand the causes of the revival of English printing which marked the last years of the century, we must remember that by 1775 Baskerville was dead. . . . There seems to have been a temporary lull in English fine printing and the kind of type-founding that contributed to it. The wood-engraving of Thomas Bewick, produced about 1780, called, nevertheless, for more brilliant and delicate letter-press than either Caslon's or Wilson's types could supply. If Baskerville's founts had been available, no doubt they would have served. . . . So the next experiments in typography were made by a little coterie composed of the Boydells, the Nicols, the Bewicks (Thomas and John), and Bulmer.

When the cuts in this book are compared with earlier impressions from wood blocks, the difference is quickly seen. The blocks are more highly wrought, yet every line is crisp and clear and the impressions are black and brilliant. When we realize that the only new technological factor of any consequence was the use of good smooth wove paper, we can appreciate its significance.

There were no other developments of note in the practice of printing during the 18th century. The old wooden hand press, unimproved except for minor devices, was still in universal use. Ink was little im-

proved; paper was handmade; type was made from hand moulds. The ink was still applied by dabbing with inking balls of wool-stuffed leather nailed to wooden forms. The leather was still kept soft by removing it and soaking it in urine, after which it was trampled for some time to complete the unsavory operation. Paper still had to be dampened overnight before printing, and freshly inked sheets were still hung to dry over cords stretched across the room.

But with a more sympathetic surface for receiving ink from relief blocks, a new avenue for wood engraving was now open. In the following year, 1797, the first volume of Bewick's finest and best-known work was published. This was the *History of British birds*, for which he and his pupils did the cuts while Ralph Beilby, his partner and former master, provided the descriptions (see figs. 12, 13, and 14.) It achieved an immense and instantaneous popularity that carried

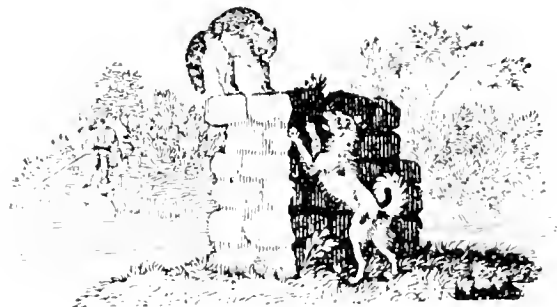


Figure 10. LAMPREY, BY THOMAS BEWICK (actual size), from *A general history of quadrupeds*, 1790, in the collections of the Library of Congress.

the artist's name over the British Isles. The attractiveness of the subject, the freshness of the medium—which could render the softness of feathers and could be interspersed with text—the powerful and decorative little tail pieces, and the comparative inexpensiveness of the volumes, brought the *Birds* into homes everywhere.

Actually, wood engraving was not immediately adopted on a wide scale. Having done without it for so long, printers and publishers made no concerted rush to avail themselves of the new type of cuts. Bewick's pupils found little of this kind of work to do before about 1830. Luke Clennell dropped engraving for painting; William Harvey restricted himself to drawing and designing; Charlton Nesbit

²⁴D. C. Thomson, *The life and works of Thomas Bewick*, London, 1882, p. 152.

²⁵D. B. Updike, *Printing types, their history, forms and use*, Cambridge and London, 1922, vol. 2, pp. 122, 123.

and John Jackson remained engravers, as did a host of lesser individuals. Dobson says:²⁶

The pupils who quitted him to seek their fortunes in London either made their way with difficulty, or turned to other pursuits, and the real popularization of wood-engraving did not take place until some years after his death.

One reason for delay in adopting the new technique may have been the danger of the block splitting, or of the sections of wood coming apart at the mortise-joints during the printing operation. If this happened, work had to be suspended until a new block was engraved, or until the sections were reglued. For periodicals with deadlines, this was a serious hazard.

Wood Engraving and the Stereotype

In any event, wood engraving did not really flourish until a practical stereotyping process was perfected. By this procedure substitute blocks of type metal could replace the wood engravings in the press, and the danger of splitting the block was eliminated. The first steps of any importance toward a practical process were made by the Earl of Stanhope around 1800, but not until Claude Genoux in France, between 1828 and 1829, developed the papier mâché or wet mat process could acceptable stereotypes of entire pages be produced.²⁷ By this method, patented on July 24, 1829, and others that followed, a number of duplicate plates of each page could be made as required for rapid printing on a battery of presses. Wood engraving now emerged as a practical method of illustration for popular publications. The *Penny Magazine* and the *Saturday Magazine*, founded in 1832, immediately made use of Genoux's stereotyping process. Dobson²⁸ describes the effect of these periodicals:

"The art of wood engraving received an astonishing impact from these publications. The engraver, instead of working merely with his own hands, has been obliged to take five or six pupils to get through the work." (Mr. Cowper's evidence before the Select Committee on Arts and Manufactures, 1835). It is difficult nowadays (1884) to understand what a revelation these two periodicals, with their representations of far countries and foreign animals, of masterpieces of painting and sculpture, were to middle-class households fifty years ago.

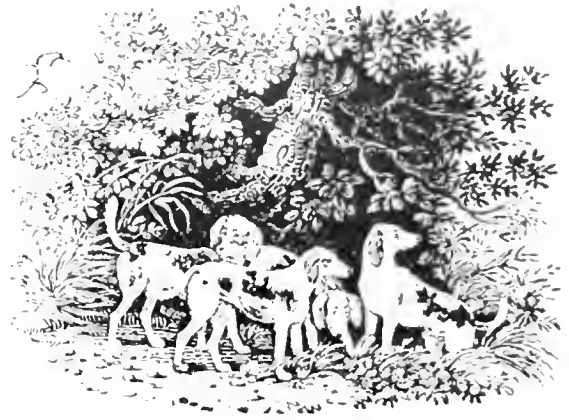


Figure 11. FAIR PLAY BY THOMAS BEWICK (actual size), engraved after a drawing by John Bewick, from *The Chase*, by William Somervile, 1796. (Photo courtesy the Library of Congress.)

We will not pursue Bewick's career further. With habits of hard work deeply ingrained, he kept at his bench until his death in 1828, engraving an awesome quantity of cuts. But he never surpassed his work on the *Birds*, although his reputation grew in proportion to the spread of wood engraving throughout the world.

The medium became more and more detailed, and eventually rivaled photography in its minute variations of tone (see figs. 15 and 16). But printing wood engravings never was a problem again. Not only was wove paper always used in this connection, but it had become much cheaper through the invention of a machine for producing it in lengths. Nicholas Louis Robert, in France, had developed and exhibited such an apparatus in 1797, at the instigation of M. Didot. John Gamble in England, working with Henry and Charles Fourdrinier, engaged a fine mechanic, Bryan Donkin, to build a machine on improved principles. The first comparatively successful one was completed in 1803. It was periodically improved, and wove paper appeared in increasing quantities. Spicer says: "Naturally these improvements and economies in the manufacture of paper were accompanied by a corresponding increase in output. Where, in 1806, a machine was capable of making 6 cwt. in twelve hours, in 1813 it could turn out double that quantity in the same time at one quarter the expense."

A. D. Spicer, *The Paper Industry*, London, 1907, p. 93.

²⁶ Dobson, *op. cit.*, (footnote 8), p. 174.

²⁷ George Kubler, *A History of Stereotyping*, New York, 1941, p. 75.

²⁸ Dobson, *op. cit.*, (footnote 8), p. 173.



FIGURE 12. WOOD ENGRAVING BY W. J. LINTON. (3-8 (ACTUAL SIZE). The detail opposite is enlarged four times to show white line-technique.



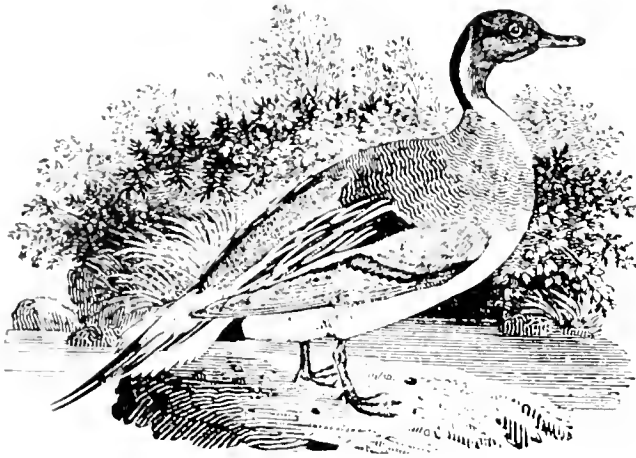


Figure 13. "PINTAIL DUCK" BY THOMAS BEWICK (actual size), from *History of British birds*, vol. 2, 1804. The detail opposite is enlarged three times.

At about the same time the all-iron Stanhope press began to be manufactured in quantity, and shortly the new inking roller invented by the indispensable Earl came into use to supplant the old inking balls. Later in the century (there is no need to go into specific detail here) calendered and coated papers were introduced, and wood engraving on these glossy papers became a medium that could reproduce wash drawings, crayon drawings, pencil drawings, and oil paintings so faithfully that all the original textures were apparent.³⁰ The engraver, concerned entirely with accurate reproduction, became little more than a mechanic who rendered pictures drawn on the blocks by an artist. In time, photographic processes came to be used for transferring pictures to the blocks and eventually, of course, photomechanical halftones replaced the wood engraver altogether.

³⁰ The electrotyping process, which came into prominence in 1839 through the experiments of Professor Jacobi in St. Petersburg and Jordan and Spencer in England, had made it possible to produce substitute plates of the highest fidelity. For fine work, these were much superior to stereotyping.

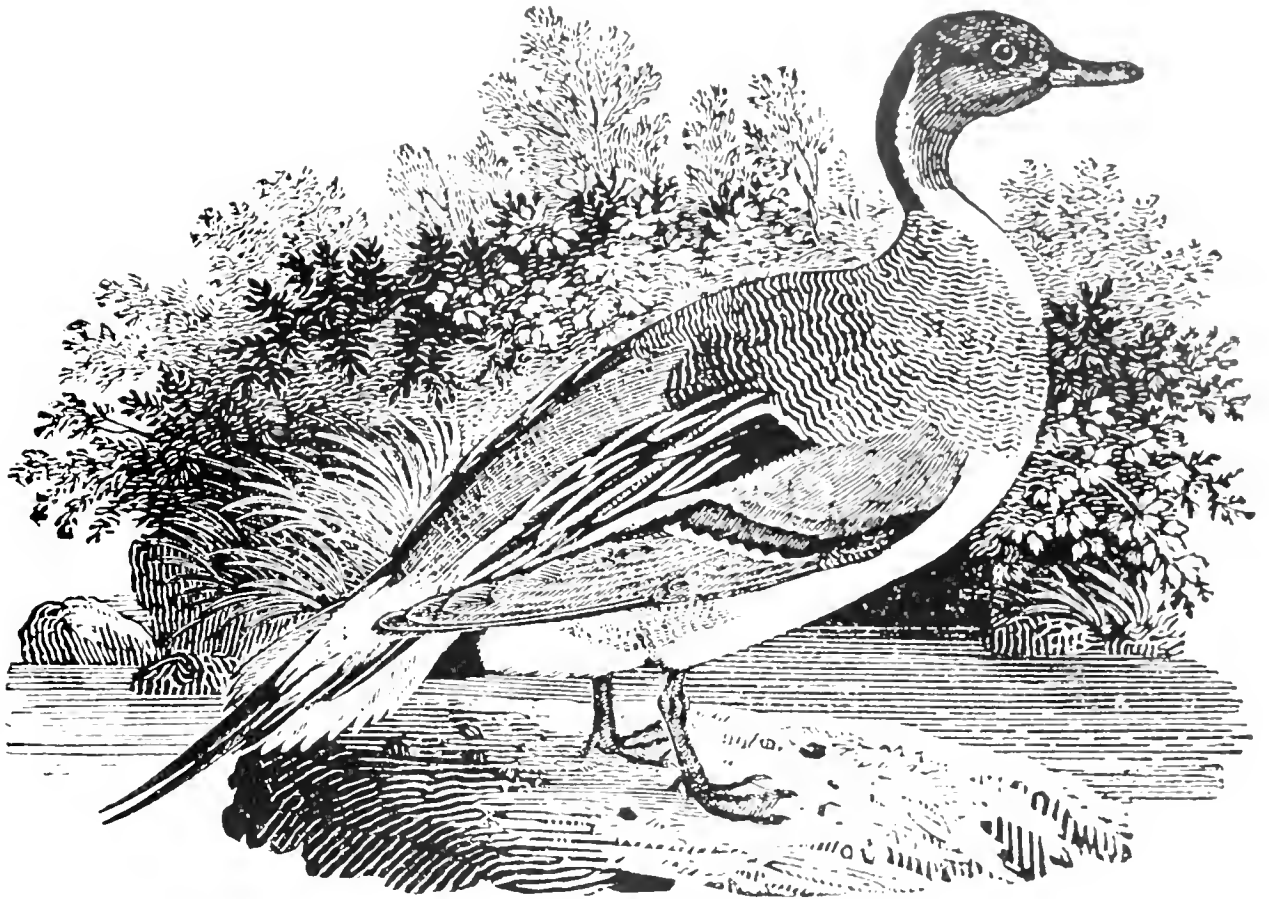
Bewick was an artist, not a reproductive craftsman. His blocks were conceived as original engravings, not as imitations of tones and textures created in another medium. If wood engraving advanced in the direction of commercialism to fill an overwhelming mass need, it was only because he had given it a technical basis. But it had greater artistic potentialities, as proved by Blake, Calvert, and Lepère, among others, and has found new life in the engravers of the 20th-century revival.

The reasons for Bewick's remarkable effectiveness can now be summed up. He succeeded, first, because he was the natural inheritor of a specifically English graphic arts process, burin-engraving on the end grain of wood. This had been practiced almost solely in England, which lacked a woodcut tradition, for about 75 years before the date he finished his apprenticeship. We know from Jackson's contemporary account that end-grain wood engraving was standard practice in England from about 1700. Bewick merely continued and refined a medium that came down to him as a national tradition.

Secondly, his country isolation and lack of academic training saved him from the inanity of repeating the old decorative devices — trophies, cartouches, classical figures, Roman ruins, and other international conventions that had lost their significance by the 1780's, although a spurious classicism was still kept alive for genteel consumption and the romantic picturesque still persisted in interior decoration.

Figure 14. FULL-PAGE ILLUSTRATION by Thomas Bewick, from *History of British birds*, vol. 1, 1797. (Actual size.)



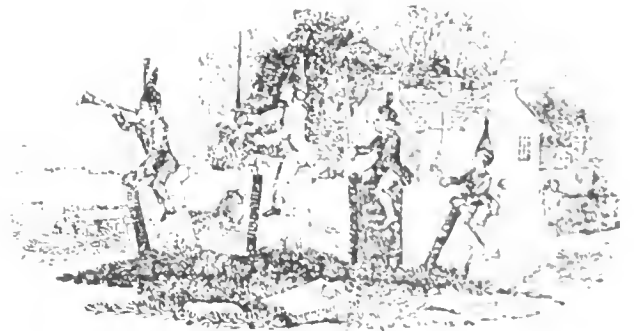


Thirdly, he looked at life and nature with a fresh eye, without preconceptions. While his lack of larger vision held him down as an artist, it contributed to his feeling for natural textures and story-telling detail. His approach to illustration, therefore, was the spontaneous expression of an observant but unimaginative nature, coated with a bitter-sweet sentiment. It was this quality, so homely and common and yet so charged with integrity, that delivered the shock of recognition to a mass audience.

Lastly, and perhaps most importantly in the long run, he was fortunate enough to live at a time when a necessary prerequisite for the physical appearance of his work, wove paper, was coming into use. Without it he would soon have had to simplify his line system, returning to older and less detailed methods, or his work would have remained unprintable.

It was the new paper that allowed him to extract unprecedented subtleties from the wood block, that made his cuts print clearly and evenly, and that encouraged the expansion of the wood engraving process. These factors, taken together, make up the phenomenon of Thomas Bewick.

Figure 15.—LALPHET. BY THOMAS BEWICK, from *History of British birds*, vol. 2, 1804. (Actual size.)



SMITHSONIAN INSTITUTION LIBRARIES



3 9088 01421 3078